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MIXED-USE HIGH RISE IN THE UK; AN URBAN RENAISSANCE?

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In many cities around the world, inner-city living is seen as a vital factor in the success of an urban centre. In recent decades in the UK, however, British cities have seen a migration of inhabitants away from the city to the suburban periphery. In an attempt to counteract this, several cities have recently created high-density / high-rise, inner-city schemes. The relationship of many of these buildings to their urban setting however – as with most tall buildings the world over – leaves much to be desired. This paper outlines the findings of experimental design research, under the directorship of the author, in the field of tall buildings and their essential relationship to 'place'. In doing this, it embraces essential strategies of mixed-use, environmentalism and increased urban connections.

1.0 Introduction

In many cities around the world, inner-city living is seen as a vital factor in the success of an urban centre – the ability to retain a percentage of the urban population, and thus vitality, in the city beyond the working day. In recent decades in the UK, however, this has not been the case. Chasing the dream of the suburban home, British cities have seen a migration of inhabitants away from the city to the suburban periphery, to the point where many city centres have become purely the domain of workers / shoppers during the daytime and exponents of 'bar culture' (which creates its own set of urban problems) in the evening. Thus whilst cities as culturally-different as Paris or Hong Kong enjoy high population densities in their urban centres, UK centres have seen a dearth of city centre living.

In the past decade in the UK however, there have been moves to counteract this and bring life beyond office hours back into the city centre. Provision of new, quality inner-city residential space has been a vital component of this strategy. Perhaps nowhere is this better exemplified than in the northern English city of Manchester, where urban density in the city centre has increased from a mere 90 people in 1991, to more than 15,000 today [1].

This move to increase the urban density of our city centres is in keeping with the strategic response to the effects of our global-consumer society on the environment. The detrimental impact of climate change emissions on the environment has been well documented [2]. In the developed world, 75% of all energy usage is accounted for by the combined effect of Buildings (50% - creation, running and maintenance) and Transport (25%) [3]. These combined sectors also account for a similarly high proportion of all climate-change emissions globally. Thus the design of cities – and the predetermining of the relationship between buildings, people and transport - is vitally important. *Figure 1* below [4] shows the relationship between urban density and gasoline consumption for a number of cities around the world. What is interesting here is the clear differential between the low urban density / high energy consumption cities of America, and the contrasting high urban density / lower energy consumption of southeast Asian cities such as Singapore and Hong Kong. Denser cities where people both live and work, thus reducing transport needs, energy consumption and consequential environmental degradation, seems inherently sensible.

Against this backdrop, the appropriateness of the tall building in the urban renaissance is – as far as the UK is concerned – still not confirmed. The popularity of tall buildings in the UK has seen dramatic pendulum swings over the past 40 years, from a time when the genre could not disassociate itself from the loathed, ubiquitous council tenement towers of the post-second world war period [5] – leading to Turkington's definition of high-rise housing in the UK as the 'doubtful guest' [6] – to the heady days of the 1980's when the commercially-driven policies of the Conservative Thatcher government led to the huge docklands redevelopment, with the American architect Cesar Pelli's Canary Wharf Tower as its flagship [7].

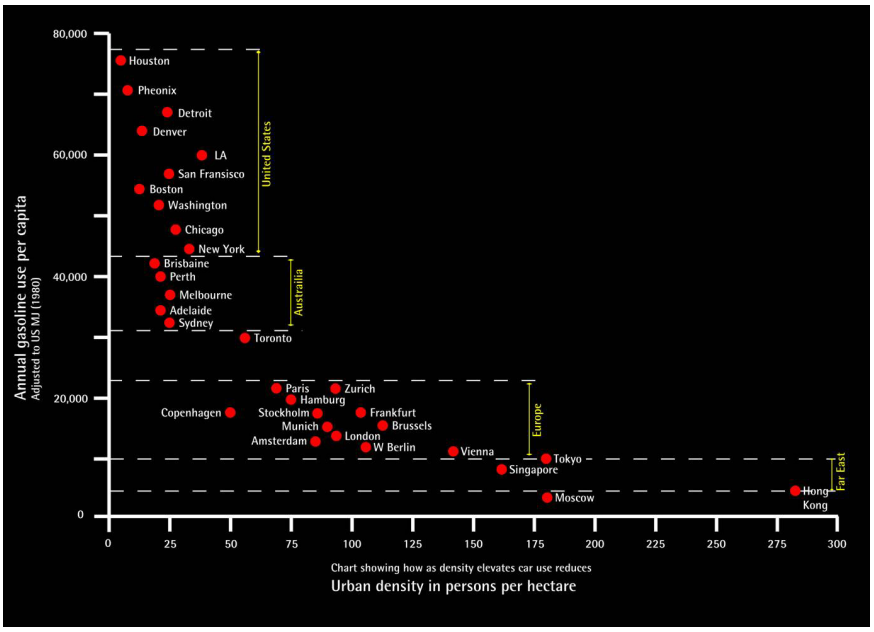

Figure 1: Graph showing the relationship between Urban density and Annual Gasoline Use for cities around the world. (Source: Newman & Kenworthy, 1989).

Today, under the enthusiastic endorsement of the Mayor of London, Ken Livingstone, tall buildings seem to be enjoying a popularity unlike anything seen previously in the UK [8]. Not everyone is convinced though. The Heritage Lobby, and in particular English Heritage, are concerned about the impact tall buildings have on historic urban fabrics such as London, and for every report that is issued in support of Tall Buildings in the UK [9] there seems to be a contradictory report condemning them [10].

The international community is still also divided on the sustainability credentials of Tall Buildings as an appropriate typology in our urban fabric. There are those that believe that the concentration of population through high-density (therefore reducing transport costs and urban / sub-urban spread) combined with the economies of scale of building tall make the typology an inherently sustainable option ([11], whilst others believe that the embodied energies involved in constructing at height, combined with the impact on the urban environment, make them inherently anti-environmental [3]. Thus each time a tall building is proposed in a UK urban centre, it is met with much scepticism and conflict, often resulting in a significant, and lengthy, planning enquiry.

Owner-occupiers and professionals involved in the creation of Tall Buildings in the UK have not helped to convince a sceptical public in this debate. Certainly most high-rise commercial towers in the UK have followed the imported standard North American model – the rectilinear, air-conditioned 'box' – but, also, very few residential towers have strove to create anything other than the vertical extrapolation of an efficient floorplan. Not only does this do nothing to enrich our city centres, this has served to create an alarming homogeneity across global urban centres on an international scale – a creation of a 'one size fits all' skyscraper 'mush' across the world – which matches in negativity the detrimental effect these buildings are having on the planet we inhabit. In short, these tall buildings are helping to destroy both the local and the global.

In an attempt to counteract this, the design research studio at the University of Nottingham's School of the Built Environment has, under the direction of the author, conducted experimental research into the design of tall buildings, in an attempt to create high rise buildings which are firmly rooted into the specifics of place i.e. tall buildings that relate to their urban context and enrich the urban centre from both a building-occupier and city-occupier viewpoint. The urban vehicle taken for this research is the City of London – a commercial centre with a very low residential population density. This paper outlines the findings of this experimental design research. A number of strategic directions that resulted can be categorised – each of which will be exemplified in greater detail to follow:

(i) The need for mixed-use.
(ii) Design responses that relate to the physical characteristics of place.
(iii) Design responses that relate to the environmental characteristics of place.
(iv) Connections – the need to move away from tall buildings as isolationist works of architecture.

2.0 The Need for Mixed Use.

The City of London is approximately one square mile in area and, as the financial heart of the city, is almost exclusively a commercial centre. It has a daily working population of approximately 300,000 people but a resident population of only 7185 (2001 Census), most of these in a single complex – the Barbican estate. Almost exclusively, new high-rise proposals for the City of London have centered on providing further commercial space (see *Table 1*).

Table 1: Current Tall Building proposals, City of London (compiled by author - various sources)

Building	*Architects*	*Primary Function*	*Floor Area / No. of floors*	*Status*
Heron Tower	Kohn Pederson Fox	Office	63,135 m² 37 floors	Approved 2001. Start on site envisaged 2006.
Minerva Tower	Grimshaws	Office	92,900 m² 50 floors	Approved 2002. Start on site envisaged 2006.
51 Lime Street	Norman Foster	Office	44,000 m² 28 floors	Approved 2002. Construction started 2005.
Leadenhall Tower	Richard Rogers	Office	48 floors	Approved 2004. Start on site envisaged 2007
Mitre Square	Sheppherd Robson	Office	32,515 m² 19 floors	Approved 2005. Start on site envisaged 2006.
100 Middlesex Street	ORMS Architects	Office	30,000 m² 25 floors	Submitted for approval 2003.
Bishopsgate Tower	Kohn Pederson Fox	Office	88,500 m² 64 floors	Submitted for approval 2005.
Camomile Street	Norma Foster	Office	20,000 m² 21 stories	Submitted for approval 2005.

The City of London is typical of many urban centres in the UK today. With the major emphasis on commercial floor space, the whole area is devoid of life beyond office hours – the population, and thus vibrancy, of the urban centre is temporal. Yet, despite this inequality in such a large urban area, there is very little movement towards re-populating the City through providing residential space. Even if there was such a desire from local government, commercial pressures on land in the area are such that single-use residential towers would be unviable. The most realistic option of encouraging citizens to re-inhabit the city is through mixed use.

Tall buildings typically deal with large floor areas and thus significant populations. In these large populations there are opportunities for a mixture of uses, in the same way that cities offer a mixture of uses. In an extrapolation of the need to make city centres more concentrated to reduce impact on the environment, an increased concentration of activities within a single tower seems sensible. This would not only provide the opportunity for live-work scenarios within a single tower but also functions traditionally confined to ground level – kindergartens, gardens, shops etc – could be introduced into the tower. This would enrich the experiential aspect of the tower in myriad ways.

Mixed use is also vital in attracting a mixture of social groups into the city. Much of the urban renaissance in the UK over the past few years has focussed on attracting young professionals (in Manchester, for example, over half of the new increased population is aged between 20-34, and 70% are single – see [1]). New residential provision has thus focussed on apartments catering for this socio-economic group. The lack of family homes, green space and car parking results in the same people moving out of the city when they are ready to start a family. Mixed use towers employing more of these facilities – and in particular open, green space within a tower – would help to counteract this.

All of the projects in the discussion to follow acknowledge this and are thus mixed-use in nature. All projects are based on real sites within the city, and address real physical, environmental and programmatic concerns. The programmatic brief for the experimental buildings requires a minimum of 45,000 squared-metres of mixed-use space – specifically office and residential space with retail, leisure and communal facilities – contained in a tower of 30 to 40 stories in height.

One of the main challenges in combining office and residential space within a mixed-use tower is the difference in optimal floorplate configuration of the differing functions. The optimal office configuration from a letting viewpoint is a concentrated core and large, open-plan, flexible floor space, whereas an optimal residential floorplate is made up of smaller-scale, cellular spaces which attenuate the length of envelope, i.e. the contact with the exterior for the placing of windows for view / ventilation. Thus, office floorplates are often deep-plan, concentrated spaces (e.g. square in plan with a centralised core), whereas residential floorplates are optimally shallow in depth and linearly stretched. This obviously presents a major challenge in combining the two functions within a single tower of consistent shape, and is one reason why there are not many truly mixed-use tall buildings around the world (for some of the more successful ones, see [12]).

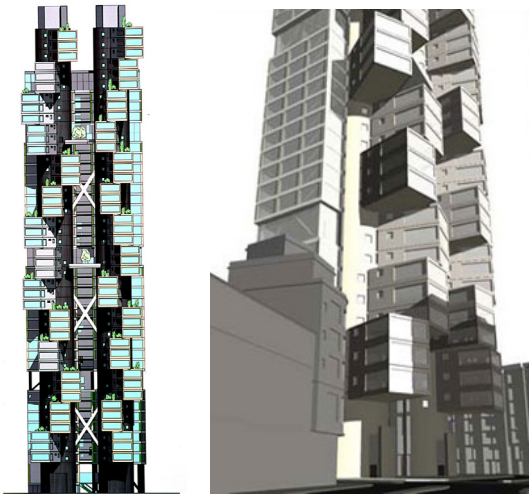

Figure 2: "The Environmental Filter", (a) Elevation, (b) Massing Image

The design investigations examined here show how designing office and residential space in a single tower can be done (for more examples of mixed-use tall building design solutions, see [13]). The "Environmental Filter" Design Response (see *Figure 2*) is proposed for a site bounded by St. Botolph's Street and Houndsditch on the edge of the City of London; the setting for the real Minerva tower proposed by Grimshaw architects. This design exploration investigates a vertical zoning of the functions, almost as separate towers placed either side of a common circulation core (see massing image). The residential function here is orientated to the south of the massing arrangement and thus acts as an environmental filter – reducing direct sunlight and thus unwanted solar gain – to the office space orientated to the north behind. This 'vertical zoning' approach has benefits in terms of vertical continuity of, for example, circulation cores and service ducting, but detrimentally reduces the size of the commercial floorplate on any given floor.

The "Sun Scoop" design response (see *Figure 3*), proposed for a site in Houndsditch, investigates the 'horizontal zoning' of functions, with two 'tiers' of residential space positioned over the office space below. This has the benefit of allowing a large, maximised, open-plan floor space for office in the lower levels (which, urbanistically, acts as a block in keeping with the common height of the surrounding urban grain), whilst allowing some freedom to the residential function above. In this particular exploration, this smaller-scale residential space leans out to the southerly direction, thus acting as a 'sun scoop' to allow light into the atria behind. The negative implications of this horizontal zoning of office and residential functions include the intrusion of vertical services and circulation on the lower function from the upper function, the lack of opportunity for interrelation between office and residential population, the lack of opportunity for shared community facilities etc. Atria are a common device in resolving the conflict between deep-plan office space and shallow-plan residential space in mixed-use towers. The Jin Mao tower in Shanghai for example has 34 floors of hotel function (thus residential scale) above 53 floors of office space, within the same sized floor plan. The concentration of the shallow-depth hotel space to the periphery in the upper part of the tower has allowed the creation of the huge, dramatic vertical atria at the centre of the plan.

The "Villages in the Sky" design investigation (see *Figure 4*) again on the Minerva Tower site, explores the relationship communal facilities can have with a vertical zoning arrangement of the office and residential functions (i.e. as separate towers). The 'public' facilities – open space, enclosed winter gardens, a nursery school etc – are proposed as the 'bridge' in between the office and residential towers and accessible by the general public. Each of the two towers has its own vertical circulation core and, in addition, a series of large, continually-moving Paternoster lifts link the central community facilities directly from the pavement level which is thus conceptually swept up into the sky. On any given floor level then, there is a mixture of office, residential and public space, achieving the intention of recreating the mixture of activities at a typical urban pavement level, as a series of 'villages' in the sky.

This is taken a stage further in the "Streets in the Air" scheme shown below (see *Figure 5*). On the site adjoining the existing Victorian Leadenhall Market, this design response takes the scale and nature of this successful, vibrant London space and recreates it as a series of 'streets' in the air. Unlike the previous scheme then, where office, residential and communal facilities are organised into distinct vertical towers / zones, this design response intersperses small-scale office, workshop, residential and public facilities – shops, bars, open space – in a random fashion, much as facilities evolve piecemeal in a typical urban street. Each street becomes a 3-storey 'community' then, hung as prefabricated 'boxes' off the giant structural frame.

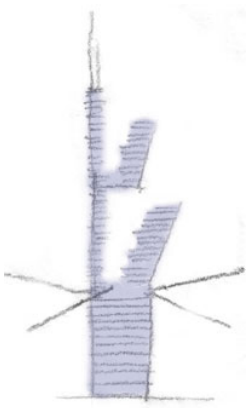

Figure 3: "The Sun Scoop"; conceptual section

Figure 4: "Villages in the Sky" (a) Conceptual Section, (b) Image

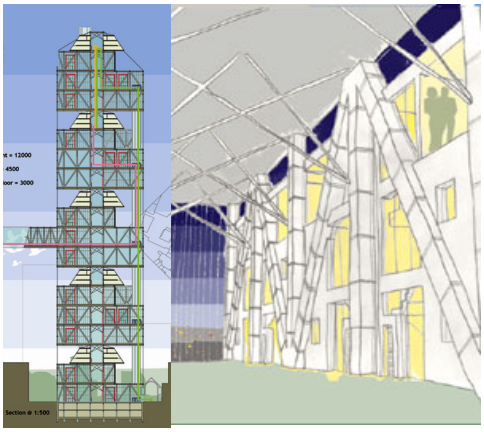

Figure 5: "Streets in the Air": (a) Section, (b) Internal 'street' view

3.0 Response to the physical characteristics of place.

The following category of design research responses, whilst embracing the concept of mixed-use, take as the main design starting point a desire to integrate into the city. Many, perhaps most, tall buildings around the world have been designed as solitary pieces of architectural sculpture on a vast scale and, as such, are non-site specific and thus transferable from one urban centre to another. The following design projects look to the specifics of the urban setting for their inspiration and, in so doing, create high rise buildings which are locked into their urban locale.

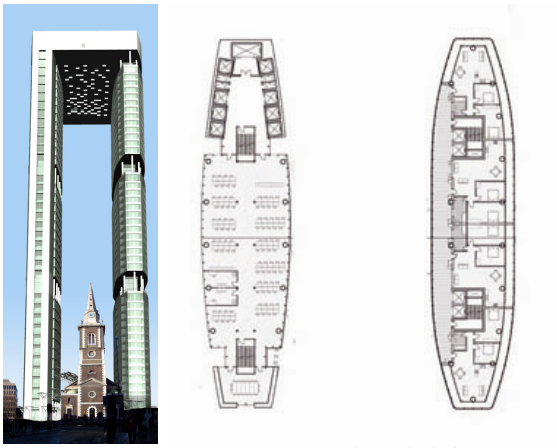

Figure 6: "Building as Frame": (a) Image, (b) Typical Plan

The "Building as Frame" design response (see *Figure 6*), again on the Minerva Tower site, takes its cue from the tiny, grade II-listed St. Botolph's church on the busy traffic island fronting the site. Whilst Grimshaw's solution for this site is to create a huge glass façade as a 'neutral' backdrop to this church (see *Figure 3c*), the alternative design response presented here acknowledges that any tall building is going to dominate the church, but that does not preclude it from having a positive relationship with it. Thus the organisation of the form serves to frame the church, with the tall building acting as an 'arch' behind. This response gives clear indication for the arrangement of the mixed uses within the tower, with one 'leg' of the tower designated for the office function, the other leg for residential. Thus whilst on first inspection the tower appears symmetrical, on closer examination it is not; placing of circulation cores, layout and façade design are different as a conscious result of optimal planning arrangements (see plan). The shallow-plan created by this approach has the additional benefit of allowing natural ventilation to both office and residential space,

via use of double skin facades as climate moderator. Structurally the design approach has major benefits also; both vertical parts of the tower act as structural 'legs', with the double-height restaurant function at the apex of the tower acting as the structural 'bridge'. The communal open gardens at levels 12 and 24 also add to this structural robustness, the open voids in the tower massing relieving wind pressures on the leeward faces.

The "Building as Billboard" design investigation (see *Figure 7*) is sited on the Heron Tower site in the heart of the City of London at 110 Bishopsgate, on a prominent corner at the junction of Bishopsgate, Houndsditch and Camomile Street. Close by are the 'Eastern High Rise Cluster' duo of Richard Seifert's 1981 Tower 42 and Norman Foster's 2003 Swiss Re Tower. This design response takes its cue directly from site, acknowledging that a high rise building has a relationship not only to the direct site context as its base, but to many other sites around the city through the visual connection between the building and that place. The design takes advantage of this, manipulating both form and skin to set up a visual dialogue with several significant places around the city, both near (e.g. St. Botolph gardens across the street) and far (e.g. St Paul's Cathedral).

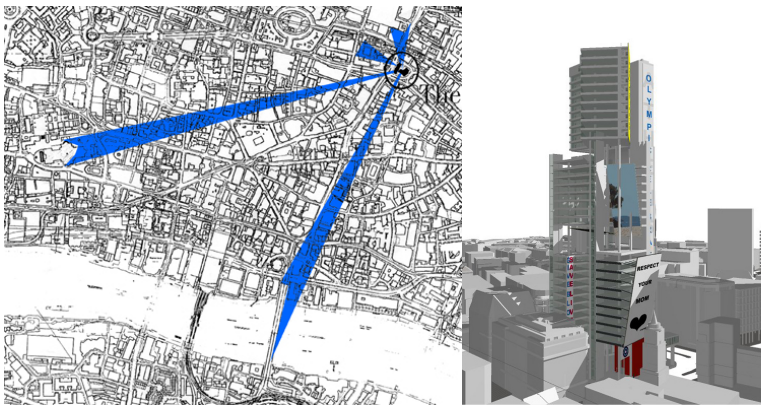

Figure 7: "Building as Billboard" (a) Relationship to Urban setting (b) Conceptual Model

The building skin itself (in some areas on the exterior of the building, in other areas on the interior behind atria) becomes a billboard, the façade 'planes' of which are positioned in both plan and sectional angle to 'speak' to the reciprocal place, often several miles away. Internal functions are arranged so as to maximise the opportunity of solid areas for billboard coverage (e.g. lift / service cores etc), whilst allowing light and air into the building, and views out, for internal occupants. This design approach has resulted in a tall building which is completely site-specific – a piece of architecture whose form and expression is dictated by its position within the City of London. Unlike most 'exported' tall buildings which are readily transportable around the world regardless of urban context, this form would not make sense in another city, though a similar design approach could be adopted elsewhere and would also result in a unique, site-specific building.

4.0 Response to the environmental characteristics of place.

The "Sun Splice" design response (see *Figure 8*) challenges one of the major problems of high rise buildings; the detrimental impact on urban environment at the ground floor plane. The shear bulk of a tower within dense urban fabric acts to cut out sun, light, air and, often, even a view of the sky. Although this has been acknowledged from the moment that the massive Equitable Building in New York prompted the introduction of the Zoning Laws of 1916 and ushered in the era of the set-back block (for a further discussion on this, see *[14]*), it is still true that the vast majority of tall buildings have a detrimental effect on the ground level urban environment around them.

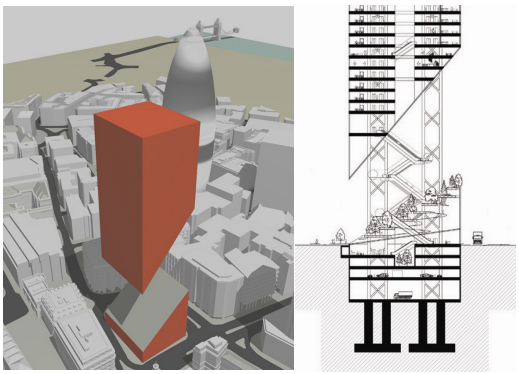

Figure 8: "The Sun Splice": (a) Conceptual model, (c) Part Section.

The Sun Splice scheme sets out to change this, by creating a high rise building that has a minimum negative effect at ground level. Rejecting the idea of lifting the building up on pilotti, which often only creates a dark, overwhelmed space beneath, the design explores the sun path at different times of the day / year and responds by creating a huge slice in the tower's mass – punctured only by structure, services and vertical circulation – to allow sun and light to penetrate the form and project to the street level below. The size and angles of enclosing planes of this huge

void are informed by the trajectory of the sun and the desire for a minimal shadow path considered in conjunction with existing surrounding buildings. Further, the lower sloping plane of the open void becomes a vegetated park, creating much-needed green space in the city.

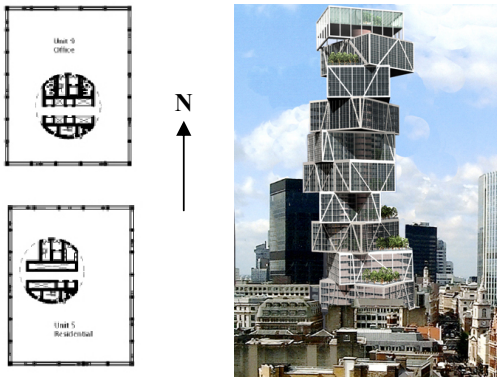

Figure 9: "Shell & Core" (a) Relationship of floor, core & north point (b) Image

The 'Shell & Core' design response (see Figure 9) explores the differing optimal relationships between shell and core for differing office and residential functions, in relation to both environmental context (in this case, sun) and physical context (view). It takes as its starting point the principle that, in the UK, residential space would optimally be orientated towards the sun (south) since sun in ventilated residential spaces is desirable, whereas office space – with its high internal heat gains (workers, equipment) and the need to reduce glare – would be optimally orientated away from the sun (north). Thus, in a residential tower, it would be beneficial to have the core placed to the north of the floor plate (to maximise useable space on the south side) and, with an office tower, vice versa. Since the project brief requires a mix of office and residential space on this approximately north-south orientated site, this project solution provides alternating six-storey 'blocks' of each function which are shifted towards north or south relative to the static core, depending on the function. The design is further rooted into the specifics of place by each block being rotated slightly in plan to be orientated towards a specific city view relative to the height of the block within the tower. The external terraced spaces created through this pushing and twisting of the blocks of floors relative to each other provide communal green space for the tower's inhabitants.

5.0 Connections: Skybridges

Within twenty years of the appearance of the first skyscrapers in Chicago at the end of the nineteenth century, people began to envisage skyscraper cities of the future. In almost all these visions, these future vertical cities incorporated circulation links at height – huge 'skybridges' spanning between towers, carrying both people and vehicles. These visions of New York pioneers such as Harvey Wiley-Corbett, Hugh Ferriss, Harry Petit et al, were soon taken up in science-fiction cinematography [15]. From 'Metropolis' onwards, almost every fictional 'city of the future' created has proposed horizontal networks in the sky in some form.

Connections at height in these new high, dense cities seemed logical to these early urban visionaries – it seemed illogical to think that cities would be extrapolated vertically, but the ground plane would remain the sole plane of connection. However, with the exception of predominantly first-floor level urban walkway networks in cities such as Hong Kong, Minneapolis and Calgary, and one-off skybridge uses in buildings such as the Petronas Towers, elevated connections have not become reality (for more on the early development of the skybridge and built examples, see [16]).

This has been to the detriment of both tall building and urban design. The benefits of skybridges are numerous – increased pedestrian mobility, improved evacuation efficiencies, increased overlap between tower functions, increased interaction of building occupants, more justification of communal/public facilities at a level other than ground, etc – and yet no city in the world has been brave enough to embrace them. Perhaps an even bigger detrimental result in the lack of connections between tall buildings is that, whilst each tower remains a design in isolation, only connected to the urban 'grid' at ground level, architects and other professionals involved in the creation of tall buildings will continue to treat them as such – one-off 'sculptures' or 'statements', to stand out from the urban form with maximum exposure. This jostling for stature and recognition from each piece of high-rise architecture has had a detrimental effect on most, if not all, high rise cities at an urban level. Any sense of urban cohesion or composition has been lost and, perhaps even worse, cities are becoming homogenised – the same urban appearance, irrespective of place, people, culture or environment.

Figure 10: 'Pavements in the Sky' design research project; City of London plan showing designated sites for design responses (source: Author)

The next area of design research creates a new urban vision for the City of London, based on a number of mixed-use towers linked by a network of skybridges. Though theoretical in its outcome, again, each project is based on a real site and programmatic brief based on a study of the city and its requirements. The network (see *Figure 10*) stretches from the boundary with the Tower Hamlets borough in the East, to the Barbican Centre in the West and incorporates existing / proposed tall buildings such as Swiss Re, Barbican, Heron, Minerva, Tower 42 and Lloyds of London. *Figure 11* below shows the physical representation of the research in model form.

It is worth examining particular solutions for the skybridges in detail in certain areas, especially at the interface with existing towers since any future vision would have to incorporate existing building stock. *Figure 12a* below shows a typical cluster of new building and existing towers. For circulation and evacuation efficiencies it has been assumed that it would be preferable to envisage the skybridge at the mid-height of population density in a tower. Since towers are of differing height then, the skybridge network would need to step in height from one tower to the next. Whereas the skybridge itself could be horizontal and the vertical step could be handled within the tower's vertical circulation core, there is also the opportunity for the skybridge itself to step, as a series of escalators as shown here (see *Figure 12a*). Although shorter buildings (both proposed or existing) may not be a viable inclusion in this network due to the large change in level to connect at their mid-height, their roofs could possibly be used as 'stepping stones' in the network, therefore reducing structural spans and giving the opportunity for inhabitants of the shorter towers to access the network directly upwards (see *Figure 12b*).

Figure 11: 'Pavements in the Sky' Design research project, City of London: site model.

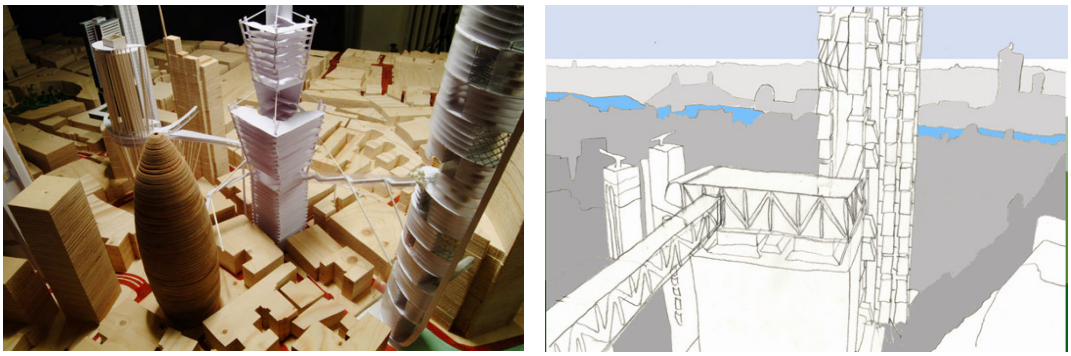

Figure 12: Skybridge design solutions: (a) Handling changes of level in skybridge network (b) Use of shorter towers as 'stepping stones'

There are myriad challenges in linking towers at height through skybridges - impact on security, structural systems, structural dynamics, internal planning, ownership and maintenance etc. In retrospective scenarios – encompassing existing buildings – the limitations of existing internal planning, vertical circulation, envelope / cladding etc in existing towers is likely to have a major influence on the design of retrospective skybridges. *Figure 13* below shows some solutions that resulted from the design research. With the existing Tower 42 for example (see *Figure 13a*), it was considered the least disruptive to create the skybridge external to the tower, supported from the periphery structure and with a link from the building's internal circulation core, but otherwise separate from it. For the connection to the Swiss Re Tower – a distinct, curvilinear form – the best solution for the form of the skybridge was an extrapolation of the diagonal structural system – the diagrid – which also informs the diamond shape cladding arrangement (see Figure 13b). This results in a perfect junctional interface with the existing tower cladding.

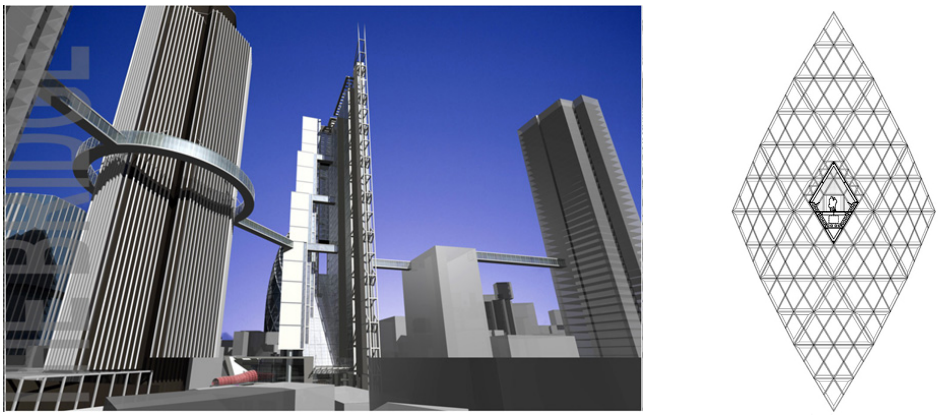

Figure 13: Retrospective skybridge solutions for connection to existing towers: (a) external solution for connection to Tower 42, (b) diamond solution inspired by Swiss Re Tower cladding

6.0 Conclusion

Historically, tall buildings have been primarily dictated by commerce and pre-occupied with their role as stand-alone, isolationist pieces of sculptural urban imagery. In the development of the typology there has been very little design consideration of their appropriateness to an urban setting, and how they could be inspired by – and relate to – that setting. Even the treasured high rise buildings of the 'heroic' pre-war periods of Chicago and New York (e.g. the Chrysler Building, 1930) showed little development from the commercial model in terms of both form and internal space. For the best part of a century, most high rise buildings have exhibited a splash of money at the base of the tower, a splash of money at the top, and very little in between.

This has resulted in an alarming – and growing – homogeneity across the cities of the world; urban centres which consist of anonymous, rectilinear, air-conditioned boxes without regard for place or time. In today's world, this is no longer acceptable. Professionals involved in the creation of tall buildings need to consider the responsibilities of their creations beyond the confines of floorplate and curtain wall. They need to consider the effect on the 'local' through consideration of the impact on the urban setting, and the effect on the 'global' through consideration of sustainability / environmentalism.

As this paper has shown, there are four areas where this can be advanced: (i) through a greater mix of functions / activities / public-private realm etc within a tower through the creation of multi-use tall buildings, (ii) through relating the design of tall buildings to the physical characteristics of site (iii) through responding to the climatic / environmental characteristics of site, and (iv) through considering the opportunities for increased 'connections' between tall buildings (e.g. skybridges), thus overlaying urban layers in the city in line with the increased height of the buildings. It is only through engaging with strategies such as these that appropriate models for tall building design can be advanced to enhance our cities in the twenty-first century.

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