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Prof. Jason Pomeroy is an architect and academic at the forefront of the Asian built environment green agenda. He graduated with distinction from the Canterbury School of Architecture before gaining a masters degree at Cambridge University. His research at Cambridge considered the socio-spatial functions of sky courts and sky gardens within the vertical city model of the 21st century. He continues to pursue this vein of research in addition to that of carbon zero development.

Pomeroy joined the London office of Broadway Malyan in 2005 to lead the sustainable agenda, and in 2008 relocated to Singapore to establish what is now one of the most successful design practices in Asia. In 2010, Pomeroy founded Broadway Malyan's Research and Development studio – a specialist group that bridges the gap between academia and professional practice by applying academic research to commercial projects in the interests of sustainability and innovation. Projects of note transcend scale and discipline and include the award winning Idea House: the first carbon zero prototype house in South East Asia; Vision Valley Malaysia: an 80,000 acre Network Garden City extension of Kuala Lumpur; the Green Plot Ratio guidelines: a method that provides a quantifiable ecological measure to landscaping within the built environment, and continued research into the role of the sky court and sky garden in the urban habitat.

In addition to codirecting the Singapore office, he lectures and publishes widely, and is the author of Idea House – the first carbon zero house in SE Asia. He is an adjunct professor at University Teknologi Malaysia and Mapua Institute of Technology; and honorary professor of the Nottingham University. He also sits on the editorial board of the Council for Tall Buildings and Urban Habitat.

> "The Green Plot Ratio assigns values to particular plants, based on the surface area of greenery. This is achieved by adapting the Leaf Area Index – a biological parameter which is used to monitor the ecological health of natural ecosystems and to mathematically model and predict metabolic processes."

The continued depletion of open spaces as a result of urbanization has also seen a subsequent reduction in greenery and gradual rise in urban temperatures that has further compromised both human comfort levels and our spatial experience of the built environment. This paper considers how we should be exploring alternative ways of greening our urban habitat which can help replenish alternative social spaces and foster a sense of community while combating negative environmental impacts associated with urban densification.

Introduction

Global population growth has had a significant impact on the urban habitats in which we live. The consensus among demographers is that by 2050, global population will be 9.2 billion people – nearly four times 1950 figures. Since 2007, for the first time in history, approximately half of the world's population lives in cities reinforcing the continued trend towards inner city transmigration in correlation to rapid economic progress (UNFPA 2007). The resulting physical transformation of our urban habitat from a city of spaces to a city of objects has been lucidly summarized by urbanist Colin Rowe's description of the diametrically opposite figure ground diagrams of the traditional and modern city – "one is almost all white, the other almost all black…in both cases, the fundamental ground promotes an entirely different category of figure – in the one object, in the other space" (Rowe 1978: 62).

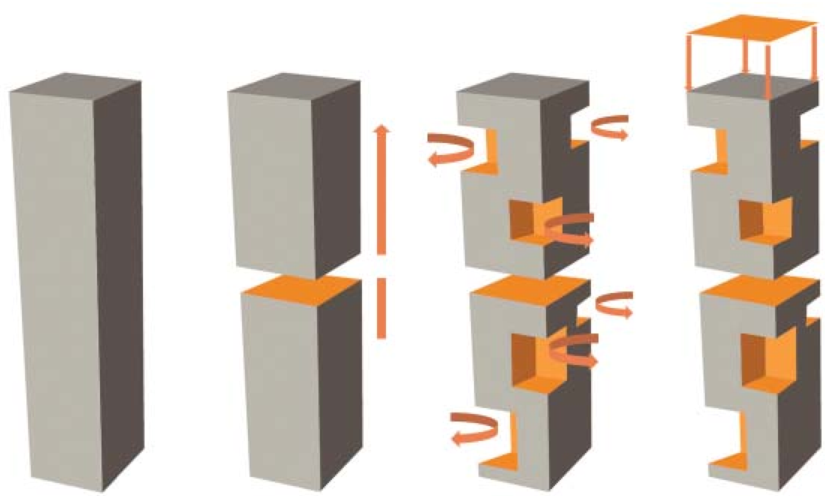

Figure 1. Sky court © Jason Pomeroy

Loss of Open Space – Socio-environmental Impacts

Asian economic growth has led cities such as Tokyo, Hong Kong and Singapore to flourish and urban densities to increase. According to scholar Christopher Tremewan, Singapore's post-colonial plans for nation building saw the city-state exert itself as a financial hub through rational policies that would lift it beyond its regional status to compete at an international level (Tremewan 1994). It increased density to not only house a transmigratory population, but also address the economic prospects that came with the expansion of its financial services sector that witnessed state-run urban renewal projects become inseparable from relocation policies for most of the local population from the city center to high-density residential blocks reminiscent of Le Corbusier's vision for the modern city.

Being on an island creates spatial constraints for Singapore which coupled with anticipated population growth from five million people in 2011 to six million by 2020,[1] will lead to continued urban densification and consequently an increase in urban temperatures as vegetated areas are surrendered to urban development (Wong et al. 2006). An increase in urban temperatures can be further attributed to anthropogenic sources, including the heat released by air conditioning plants; automobiles; artificial hard surfaces (such as roads, pavements and façades); heat stored and released by complex high thermal mass urban structures; or a decrease in surface moisture that could otherwise cool the immediate environment through evapo-transpiration (Rizwan et al 2008: 120). Studies have also shown that the high-rise, high thermal mass building typology further magnifies the impact on the urban climate, causing an Urban Heat Island (UHI) effect. This can be characterized by the differences in temperature between typically cooler rural areas and warmer urban areas (Arnfield 1999, Wong 2010, Chua 2005). The negative impact of replacing open space and its landscape with building structures (thus exacerbating UHI) include increased health risks through higher ambient temperatures; aggravated atmospheric pollution; increased emissions of ozone precursors; and increased energy consumption for cooling in the magnitude of 5% for every one degree of ambient temperature rise (Wong 2003).

Variances in the UHI has been found to also correlate to different land uses. Singapore's urban morphology is made up of an array of object driven configurations ranging from tall to medium to low-rise developments. Commercial, industrial and residential land uses characterize the island, with a predominance of residential blocks at the peripheries set within a verdant landscape; a nature reserve to the north, industrial warehouses and business parks to the west; and a centrally located business district defined by tall buildings. Studies have shown that the industrial and business parks to the west and the central business district have the highest urban heat island intensities followed by residential areas and parkland with respective descending temperatures (Jusuf et al. 2007: 232–242). This suggests that the inclusion of greenery helps reduce ambient temperatures.

An additional consequence of reducing open space is the potential loss of community vitality. Historically, the rehousing of people into high-density environments with, in the best case, supporting communal facilities and indoor streets and outdoor raised plazas, can be attributed to the early vision of French philosopher François Marie Charles Fourier and later Swiss-born French architect, designer, and urbanist Le Corbusier; but at the same time signaled the death knell of how these spaces were to be used by communities (Frampton, 1992). Various segments of society and entire neighborhoods accustomed to low-rise urban environments that permitted casual interaction were being dismantled and re-located into high-rise, urban environments. Groups of people that once gathered to do their laundry or share in common activities were finding that spatial mechanisms that permitted communal activity and spontaneous chance meetings with neighbors were being socially and spatially engineered – increasingly eradicating the forums that encouraged and permitted communal activities to take place.

The reintegration of open space in an urban environment and tall building typology in a fashion similar to the space/object hybrid described by Colin Rowe and Fred Koetter in their book Collage City, largely acknowledges how well designed space offers socio-environmental benefits. To begin with, purposeful space can promote good health, enhance productivity, and foster the social well being of the individual, group or association. In addition, the space can provide natural light, ventilation, and opportunities for greenery benefiting from the "carbon well being" of the built environment.

The Sky Court and Sky Garden Within the New Hybrid

The gradual depletion of public open spaces has seen the birth of alternative, privatized, social spaces that have sought to offer a socio-environmental balance. The sequential arrivals of the 18th century court, the 19th century galleria, and the 20th century roof top garden, have progressed to social space models (including the retail mall and the hotel lobby) within private objects of speculation that have collectively helped replenish the loss of open space for social interaction. The inclusion of privately managed social spaces with the traditional public domain, including streets and squares, has sought to balance space within the object to create a hybrid that endeavours to recapture elements of public life within the private curtillage (land immediately surrounding a house or dwelling) – despite ambiguous classifications as to whether they are public, semi-public or private in their usage. Sky courts within the new hybrid are increasingly becoming an addition to the urban habitat's open space infrastructure continuing a line of spatial development.

Sky courts are defined by its interstitial spaces that balance the figurative semi-public void within the form of the (private) tall building object (see Figure 1). Just as one normally

[1] http://www.singstat.gov.sg [accessed June 9, 2010].

... principles

> “High-rise construction is such a complex issue that I don’t think the normal zoning procedures are sufficient... Rather, we need a citywide statement of principles.”
>
> *Tuomas Rajajärvi, the head of the Helsinki City Planning Department, regarding the overall policy related to skyscrapers in Central Helsinki. From "Central Helsinki to Be Skyscraper-free Zone?," YLE Helsinki, November 25, 2011*

finds a proportion of open space in relation to the built-up area in "ground scraping" mixed-use developments, sky courts start to vertically balance open space to built-up area ratios within the tall building. In doing so, they can help foster community through the provision of open space for the interaction of different segments of society as well as provide opportunities for natural daylight and ventilation deeper into floor plates – enhancing the internal environment and making it more habitable.

Ken Yeang's Singapore National Library development aptly demonstrates the incorporation of sky courts to achieve socio-environmental benefits (see Figure 2). It has over 6,300 square meters (67,800 square feet) of designated green space that acts as an environmental buffer to the low-angled east and west orientated sun by reducing solar heat gain while improving the general working environment for student groups that gather to study. It particularly offers a potential positive environmental and psychological benefit derived from the landscaping. Socio-environmental considerations need not be confined to the realms of exterior spaces however, as demonstrated in architect Norman Foster's Commerzbank in Frankfurt, Germany (see Figure 3a and 3b). Its four-story high sealed sky courts rise through the height of the building, rotating every four stories to the next face. These spaces provide a social dimension for office employees to use as places to meet, hold events, lunches or work in private.

Sky courts, in their interstitial positioning in a tall building, can also be a useful source of convenience and amenities negating the need to travel to the ground level for shopping or recreation. As tall buildings increasingly embrace a mixed-use design, sky courts provide a forum to develop new social relationships among the buildings' occupants.

Just as spaces between a horizontal mix of uses can be places of recreation and amenity that foster a sense of community, so too can sky courts act as the socio-spatial "gel" that glues a mix of vertical uses with congregants and associations that can promote vertical communities. The Shard London Bridge, a development in progress in the United Kingdom, is a case in point (see Figure 4). Separating the commercial sections from residential spaces will be a three-story sky court at the mid-level that acts as the community space incorporating disparate functions. This space is designed to not only provide memorable views of London, but also house retail, bars, restaurants, leisure destinations, performance and exhibition activities as well as social spaces for the tower's inhabitants and the broader community.

In addition to improving the internal environment, the inclusion of sky gardens at the top of tall buildings can also provide opportunities to view the skyline (and thus be income generating), or provide a place for segments of society with similar interests to interact, play or relax. The Marina Bay Sands project in Singapore is a resort complex crowned by a 1.2-hectare (3-acre) sky park 200 meters (656 feet) above the ground (see Figure 5a and 5b). Its rooftop bars, restaurants, and observation deck, set within a garden setting, has become a popular destination

Figure 2. Singapore National Library – sky court © Jason Pomeroy

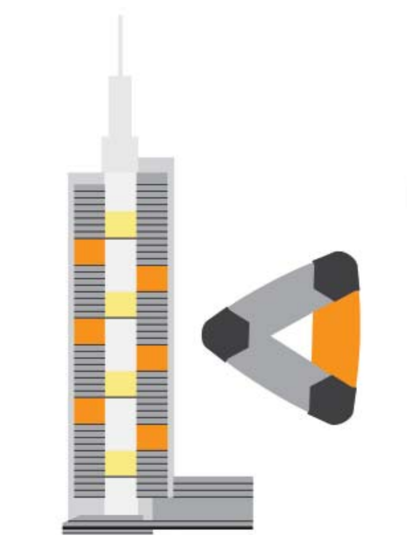

Figure 3a. Commerzbank, Frankfurt – plan and sectional diagram © Jason Pomeroy

Figure 3b. Commerzbank, Frankfurt – sky court © Joanna Gonçalves

Figure 4. The Shard, London – the sky court © Sellar Group

providing an alternative environment for locals and tourists alike to interact and view the Singapore skyline. Its rooftop pool and performance areas provide a place of recreation and amenity for fee paying hotel guests.

The Singapore National Library, Marina Bay Sands and a new wave of both private and public residential developments in Singapore (such as Newton Suites and the Pinnacle respectively) are increasingly incorporating sky courts and sky rise greenery. It is a credit to the Singapore government's implementation of planning policies that advocate for the incorporation of planted sky courts and sky gardens into high-density developments to encourage more conducive communal spaces. Developers are incentivized by the opportunity to deduct sky courts and sky gardens (barring certain stipulations) from their gross floor area calculation – essentially providing an opportunity to increase building density elsewhere and sell a more sustainable development at a premium under the auspices of providing vertical open spaces (URA 2008).

What the above demonstrates is the social, economic, environmental, cultural and spatial importance of sky courts and sky gardens which enhance the environment for collective health and well being by both improving human comfort levels and enhancing the overall experience of the urban setting. With rapidly densifying urban areas for a growing population, Singapore is faced with having to address the impacts of UHI in densely populated areas and also to provide alternative habitable social spaces which foster a sense of community. It is especially pertinent as the existing green spaces are potentially being depleted through urbanization unless it has been specifically planned for retention and enhancement. The challenge, therefore, lies in looking at alternative means to greening urban areas that explores diagonal and vertical planes in addition to the horizontal plane, podium, or rooftop for the predominant commercial, industrial, and residential land uses in Singapore where land is constrained. Furthermore, the ability to establish quantitative values for different types of greenery can help ascertain suitable ratio's for greenery and the built environment for different commercial, industrial and residential sites and ultimately establish the optimum ratio of greenery in relation to cost. This allows us to consider the green plot ratio.

Figure 5a. Marina Bay Sands, Singapore © Safdie Architects

Figure 5b. The sky park on top of Marina Bay Sands © Phillip Oldfield

Defining the Green Plot Ratio

Singapore's cultural imperative of creating a garden city has seen the development of far reaching legislative guidelines that promote the replenishment of greenery as well as the incorporation of sky courts and landscaped terraces in a bid to restore balance in an increasingly dense environment (Tan 2010). While these factors go far in balancing social, economic, and environmental parameters with the cultural and spatial intricacies of the city-state, the more objective aspects of implementing landscape design guidelines that respond to such parameters, while embracing a 6th parameter – technology, has until now been left unanswered.

This has led to the formulation of more quantifiable measures of planting to ensure that adverse climatic effects of high-density development can be mitigated through more balanced architectural and integrated landscape design with the government's commitment to researching the effects of rooftop gardens. Vertical and horizontal planting can be seen in what has been defined as the Green Plot Ratio (GnPR). Planted surfaces are an effective way of counteracting the absorption of heat in the building fabric and its subsequent re-radiation as well as enhancing the qualities of open space. The Green Plot Ratio addresses this issue by assigning values to particular plants, based on the surface area of greenery (see Figure 6). This is achieved by adapting the Leaf Area Index – a biological parameter which is used to monitor the ecological health of natural ecosystems and to mathematically model and predict metabolic processes. As such, it can be used to quantify planning metric in biological terms (Ong 2003). For instance, a hypothetical site that has 12 trees (and therefore a particular GnPR value) may be developed and realize a subsequent removal of trees. By assigning values to different types of planting, the ability to replenish the same "green value" of the 12 trees by alternative means (for instance turf and shrubs across the vertical or diagonal surfaces) will ensure a balance of built area and green leaf area is retained (or enhanced) on the site for its correlating social, economic and environmental benefits. These include enhanced carbon sequestration, water retention, and reduction in ambient temperatures; lower running costs; and more pleasurable environments in which to interact.

Turf, palm, shrubs and trees are the major groups that are assigned green plot ratio values based on the leaf area index. Turf has the lowest GnPR at 2.0, as the leaf area index of a blade of grass is less than that of the other categories. Despite palm trees being larger structures, their leaf area index is still less than a shrub and has a value of 2.5. Shrubs, given their greater density of leaf coverage, have a value of 3.5; while the tree has the highest leaf area index at 4.0. The ability to quantifiably ascertain the effectiveness of planting on the building through the creation of a green metric advances the integration of architecture with landscape as opposed to being considered in isolation.

A research project involving the assessment of 100 buildings involving various Singaporean agencies that oversee the built environment, National University of Singapore, and Broadway Malyan has allowed mean green plot ratio values to be calculated for existing commercial, industrial and residential sectors – giving a quantitative indication of existing greenery patterns according to building typology within each sector. It has also provided the opportunity to establish landscape guidelines to further enhance the (new) urban habitat by applying landscaping technologies to new buildings with tangible incremental costs associated with the additional greenery. The landscaping technologies within the horizontal, diagonal or vertical plane were categorized into extensive green roof, intensive green roof, brown roof, green wall systems, planter boxes and grid structures and formed an effective modular "kit of parts" that could be applied to:

- the ground plane (trees, palms, shrubs, and turf in their raw state, horizontal trellis structures);
- the podium level (trees, palms, shrubs, and turf in their raw state, horizontal trellis structures, intensive or extensive green roof);
- the building (trees, palms, shrubs, and turf in their raw state, horizontal and vertical trellis structures, planter boxes, green wall); and
- the roof (trees, palms, shrubs, and turf in their raw state, horizontal trellis structures, intensive or extensive green roof, brown roof).

Plant	Grass	Shrub	Palm	Tree
Leaf Area Index (LAI)*	Grass LAI = 1	Shrubs LAI = 2	Palm LAI = 3	Trees LAI = 6
Proportion Planted	6/6	3/6	2/6	1/6
Green Plot Ratio	6/6 X 1 = 1	3/6 X 2 = 1	2/6 X 3 = 1	1/6 X 6 = 1

**The LAI value of grass, shrubs and trees shown are only quoted for the purpose of showing how the green plot ratio is calculated. Actual figures may vary.*

Source of Green Plot Ratio: Dr. Ong Boon Lay. NUS.

Figure 6. Green Plot Ratio calculated based on the value of particular plants © Dr. Ong Boon Lay

A 1-square meter (10.8-square foot) module was used as the common metric in order to reduce bespoke design on the various sites and allow cross comparison of planting density and cost. The individual modules within the kit of parts were then each assigned a GnPR figure and cost per square meter that included any remedial structural alterations in order to create the one-square meter landscape module. The research has culminated in mean GnPR values for existing commercial, industrial and residential building typologies and proposed enhanced GnPR values for sectors with respective costs associated. The next phase of our research is gauging energy savings and social behavior in correlation to GnPR values.

We have furthermore applied such strategies to green projects within the region, including a bioclimatic mixed-use cultural office development in Kuala Lumpur. Ken@TTDI demonstrates not only the importance of creating a balance of open spaces with built up area to create greater opportunities for social interaction and recreation, but also the benefits of being able to plant such spaces in order to enhance biodiversity; reduce ambient temperatures; and create more conducive social environments that start to integrate landscape with architecture (see Figure 7). Furthermore, it treats the greenery as an environmental skin that enhances thermal performance. Early results demonstrate its ability to reduce direct radiation by 68%rom around 700 kilowatt hours (kWh) for a conventional Malaysian office façade to 224 kWh for a green skin of expanded mesh grating and vertical planting within our proposed model. It also helps counteract glare by up to 60%.

Conclusion

Italian Architect and Surveyor Giambattista Nolli's plan of Rome in 1748 revolutionized the way we conceive cities and its open spaces. It clearly identified a hierarchy of outdoor rooms as the spaces left over after the urban infill of buildings was blackened out. Such a mapping exercise can clearly demonstrate the fundamental shift in precedence of space over object in the 18th century to the object

Figure 7. Ken @ TTDI © Ken Yeang

over space by the 20th century. While this has as much to do with slum clearance as it does technological advancements in transport infrastructure at the turn of the century (Hall 2002), it also highlights the increasing privatization of space and the decline of the public realm (Sennett 1976). The ability to provide a balance – the open spaces of sky courts and sky gardens with the built up area of the tall building object – allows us to therefore challenge the conventional 20th century tall building approach of self-same repetition in favor of a more hybridist form.

Sky courts and sky gardens in their current guise can be deemed semi-public, social spaces with public domain characteristics. They form part of a hierarchical network of open spaces that replenish and complement the existing open space designs on the ground in order to rekindle the critical qualities that define the civic realm and wider community (Pomeroy 2007). They are spatially constrained by the tall buildings that retain them, often strictly classified as to their function, and socially limited by the implicit rules of a community or the explicit rules of the institution, company, association or group that governs them (Pomeroy 2010). When more integrated within the building's internal planning and its vertical circulation methods, sky courts and sky gardens can provide an ease of movement as a transitional space such as "the galleria," or income generation as a destination space much like "the court" model. Increased traffic through these social spaces provides greater opportunities for chance meetings and the ability to make new relationships through more integrated movement patterns. This in turn enhances security through surveillance, helping to discern a friend from a stranger. Sky courts can also provide greater daylight penetration and natural ventilation deeper into the traditional floor plate. When planting is incorporated, the ability to cool the immediate environment through evapo-transpiration can improve thermal comfort levels, reduce urban heat island effect, and offer a more conducive environment for social interaction given its socio-physiological benefits (Pomeroy 2010). It is at this socio-environmental juncture that the design of sky courts and sky gardens can be enhanced via more objective means. The "Space Syntax Method," developed by Bill Hillier and Julienne Hanson at The Bartlett, University College London, provides a mechanism for a predictive theory of mass movement based on rational choices of an individuals' spatial cognition. When this is coupled with Singapore's landscape architect Dr. Ong Boon Lay's more objective measures of urban greenery and both are then set within a framework of an environmental model that is responsive to the climatic conditions of a place, perhaps more conducive spaces can be created that will help foster more successful vertical communities and a greener urban habitat. ■

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