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Authors:	Swinal R Samant, National University of Singapore Srilakshmi Menon, National University of Singapore
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Exploring New Paradigms in High-Density Vertical Hybrids

Swinal Samant Ravindranath and Srilakshmi Jayasankar Menon†

Department of Architecture, National University of Singapore

Abstract

By the year 2050, the world population is set to increase to 9 billion people, of which 66% will be living in cities. It is argued that this will inevitably lead to further urban densification and soaring, inhumane and dense vertical environments. However, innovative and disruptive technologies impacting all realms of life means that we will also live, work, play, learn and make in novel ways, the beginnings of which are already becoming evident. These present opportunities for reimagining city environments, and in particular tall buildings, with a focus on reducing redundancies and re-appropriating existing buildings, creating novel hybrid environments, incorporating green and social democratic spaces, and integrating multiple modes of transport. This paper examines how vertical cities may perhaps be dense, resource efficient, and yet humane, presenting three possible scenarios for Singapore's context, which are, however, common to many Asian high-density urban environments. The scenarios presented are the outcome of Final-Year Thesis Projects undertaken by final-year architecture students at the National University of Singapore (NUS) in 2017.

Keywords: Mixed-use, Vertical hybrids, High-density living

1. Introduction

By the year 2050, 66% of the global population is estimated to reside in large, dense, service- and industry-based urban agglomerations, transitioning from small, dispersed agrarian settlements (Montgomery et al., 2004) and posing a massive challenge to the built environment (UNDESP, 2014). Housing, education, healthcare, transportation and other infrastructure for the growing population will require efficient development measures in cognizance of climate change impacts, resource scarcity and rising energy costs. Furthermore, emerging disruptive technologies such as cloud-based systems, robotics, autonomous vehicles, advanced materials, renewable energy, etc. are expected to impact our lifestyles (Manyika et al., 2013) and provoke the novel use of spaces that could potentially transform the built environment radically. Therefore, an assertive shift in the current urban fabric, and in that of the vertical development model is expected. The paper hypothesizes that the aforementioned challenges necessitate the rethinking of tall buildings with an emphasis on mixed-use hybridization, multi-level access and transit integration, and the incorporation of green and social spaces, as outlined below. It argues, that in doing so, vertical cities may perhaps be dense, resource-efficient, and yet, humane, and presents three possible scenarios for the Singapore context, which would be common to many Asian high-density urban environments. The scenarios presented are the outcome of Final-Year Thesis Projects undertaken by final-year architecture students at the National University of Singapore (NUS) in 2017.

†Corresponding author: Srilakshmi Jayasankar Menon
Tel: +65-6601-3437; Fax: +65-6775-3078
E-mail: akisjm@nus.edu.sg

2. Literature Review

2.1. Mono-Functional Megatowers to Mixed-Use Vertical Hybrids

Early modernist planning ideas of segregated-use zoning are often implemented in tall buildings, generating mono-functional megatowers that "concentrate nodes of the same type in homogenous urban regions" (Salingaros, 1998). A prime example of this is the familiar office towers within the Central Business Districts that witness high user volumes during work hours and negligible activity on the weekends and during holidays. In principle, mono-functionality was enforced for the efficient utilization of resources, however, the daily cycles of peaks and troughs in usage suggest otherwise. Furthermore, in a comparative study between urban high-rise living and suburban low-rise living, it was observed that downtown (homogenous urban centers) residents spent 11 percent more time traveling per year, coupled with 9 percent greater vehicular dependence dedicated to commuting to shops, restaurants and entertainment spaces (Du et al., 2017). This refers to the inefficiencies associated with the mono-use model. Most planning theorists, therefore, agree on the functional, environmental, and social benefits of mixing land use (Talen and Knaap, 2003) – particularly the fine-grained mixed-use model (within individual buildings) – as a cru-

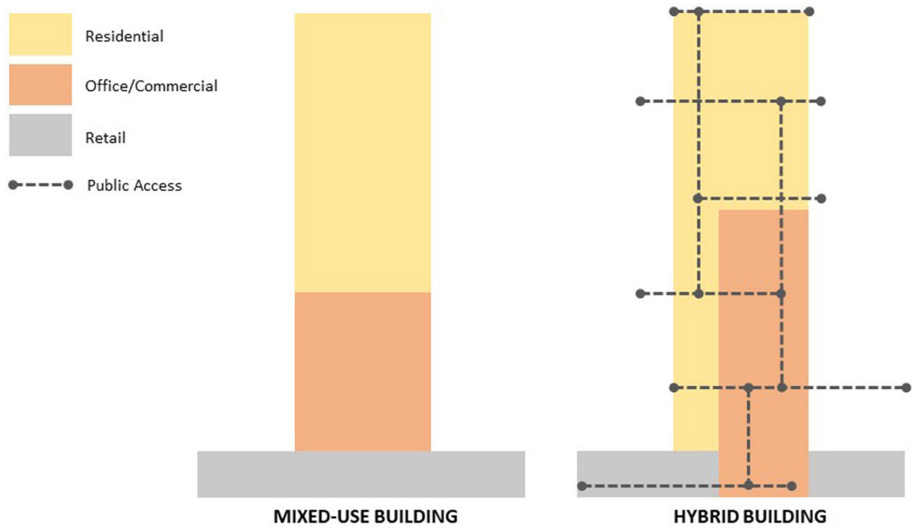


Figure 1. Differences between Mixed-Use and Hybrid Buildings (Credits: Author's Own).

cial component of urban vitality (Rowley, 1996; Jacobs, 1961).

The pervasiveness of technology such as social media, mobile devices and e-commerce in our daily lives has led to the continuous evolution of personal and organizational systems (Robinson, 2013). This has necessitated the built environment to accommodate evolving user demands and their immediate context, (Schmidt III et al., 2010) and has led designers to innovate spatial typologies that are flexible and multi-functional. Buildings now require internal infrastructures that integrate such spaces with their surroundings and, even further, connect to the city-wide network of movements through transit integration.

Tall buildings have been evolving in response to these challenges and opportunities, and the past few decades have seen a rise in mixed-use developments the world over, and to the coining of the term "vertical hybrids".

"(Vertical) hybrids are (tall) buildings which have the mixed-use gene in its gene code, that revitalizes the urban scene and saves space." – Steven Holl (Holl 2011)

Vertical Hybrids are characterized by high programmatic complexity that is in constant exchange with its surroundings. Unlike mixed-use buildings that stack up various programs within their built form, vertical hybrids recognise the interconnectivity between programs with an understanding of "the social dimension of users" and relate them back into the urban context (Fig. 1)(Per et al., 2014).

The mixed-use programs are mutually synergistic, suggesting unconventional methods of space usage that support co-existence, cohabitation and integration often enabled by advancements in technology and catering to changing lifestyles.

"The intimacy of private life and the sociability of public life dwell within the hybrid and produce constant activity, making it a building working full-time." (Per et al., 2014)

Fenton (1985) was one of the earliest to categorize the architectural form of high-rise, mixed-use buildings into three types: the "fabric", "graft" hybrid the "monolith" hybrids. The fabric hybrid borrows from the grain of the surrounding urban context, while the graft hybrid represents a combination of different building forms within an urban block that articulate the different functions. The monolith hybrid is a high-rise structure that merges different functions under a unifying skin. Complex forms; architectural layouts; hybrid indoor-outdoor interfaces; underground, multi-level and elevated public spaces are some of the design variants of such hybrid developments.

For example, *Linked Hybrid* in Beijing by Steven Holl (Fig. 2) is an example of a "graft hybrid", which integrates mixed-uses within its eight, high-density blocks (68 meters high) connected by skybridges.

Further intensification of the mixed-use model within hybrid buildings is made possible by the concepts of time- and space-sharing. There is an emerging nexus of industry and academia, for example, fuelling the growth of a rich ecosystem of future-ready learners (Hagel et al., 2015) and a gig economy that relies on "crowd-work", "work-on-demand", or work across different time zones. The resultant fast-changing, creative, problem-solving and multi-disciplinary work cultures with varied schedules warrant flexible spaces (Stefano, 2015) with heightened social interaction that "business-as-usual" spaces may fail to provide. These lifestyle changes also necessitate a variety of services to be available at different times of the day, subtending to the "24-hour" culture (Ang, 2016). Therefore, the ensuing vertical, high-density hybrid buildings need to

Figure 2. Linked Hybrid, Beijing (Credits: Terri Meyer Boake via CTBUH).

support live-work-play-learn-make environments incorporating a great deal of flexibility, e.g., "time-sharing" of spaces and reduced redundancies.

2.2. Multi-Level Access and Transit Integration

Buildings with large user catchments that are only accessible at the ground level "burden city infrastructure" such as roads and sidewalks during peak hours, impacting the efficiency of fast-paced urban lifestyles. Therefore, multiple/alternative connections to the urban networks, while preventing an "over-concentration of nodes", are critical (Kunstler and Salingaros, 2001). Buildings require internal infrastructure that integrates with their surroundings, and even further, connects to the city-wide network of movements at multiple levels (both vertical and horizontal). Furthermore, increasing urban density necessitates "two-level circulation" segregating pedestrians from vehicular traffic (Nielsen, 2007) through the use of footbridges, podiums, subways, car-parks, atria and lobbies into a unified environment (Tan and Xue, 2015). The points of ingress and egress, accessibility to commuters, and adjacency to open spaces provide opportunities to re-activate points of interaction and provide greater local and global integration (Heng and Rashid, 2006; Pomeroy, 2011). This is reflected in contemporary urban development initiatives that have strategized extensive, multi-level pedestrian systems (that also support[1] the use of Personal Mobility Devices) via linking of hybrid buildings to major transport interchanges to enable seamless movement of people (Planning Department 1999). *Kyoto Station* by Hiroshi Hara is one such stellar example of a hybrid building which combines transit infrastructure with mixed-use programs (shopping, F&B and entertainment) through the juxta-positioning of the atrium typology with traditional street spaces, offering multiple access routes on different levels within this 15-story building. The spatial layout sculpts a valley-like hollow space with an artificial interior landscape that "reflects the complexity of Japanese cityscapes: vertical dimensions, interlocking networks, fluidities of space and discontinuities of scale" (Cho et al., 2016). Hybrid buildings that integrate multiple transport modes and pedestrian-friendly networks within vertical developments, therefore, hold a significant potential to re-envision dense urban environments, such that they are more efficient and humane.

2.3. Green and Social Spaces

"The most successful cities of the past were those where people and buildings were in a certain balance with nature." – Constantine Doxiades (Blake 1977)

Mechanized work-cultures, along with tall building environments with low ground accessibility and overcrowding are known to provide users with low levels of "satisfaction" (Gifford 2011). This is augmented by profit-driven developments in prime locations that seek to economize on floor space at the expense of green and social interaction spaces.

Vertical hybrids exhibit perforation of the building form with the strategic positioning of green, open spatial features, such as sky decks, skybridges, sky gardens and the like, that break down the soaring verticality into discernible human scale and soften the harshness of the built environment. "Multiplying the ground" on upper levels with various types of greenery and water elements improves the

[1]For e.g., the Active Mobility Bill in Singapore supports the use of Personal Mobility Devices (PMD) as a green, convenient and efficient option for first- and last-mile journeys supported by contiguous urban pathways.

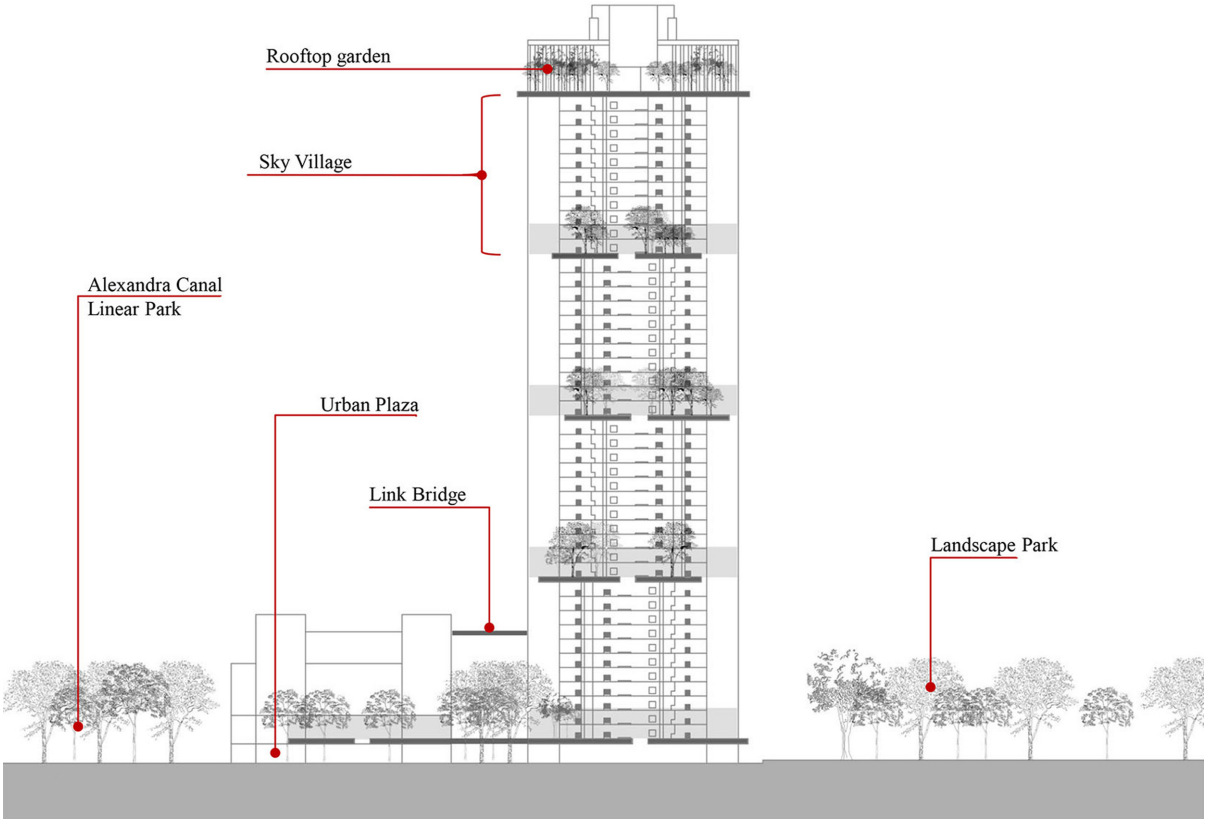


Figure 3. Vertical distribution of greenery, SkyVille @ Dawson (Credit: Authors Own).

overall aesthetic quality, contributing to calm, restorative and stress-relieving environments (Ulrich et al., 1991). Such spaces create important opportunities for formal and informal interactions, alongside social activities such as urban farming, and community gardens that may help mitigate consequences of high-rise living while invoking a sense of belonging to the building (Cho et al., 2016; Yuen and Hien, 2005).

SkyVille @ Dawson, Singapore by WOHA is a high-rise public housing development that demonstrates a balance between high-density living and social amenity in its innovative use of sky gardens at strategic levels, creating "vertical villages in the sky" (Fig. 3). Units are located at a maximum of five stories away from the sky gardens that serve as social nodes fostering daily interactions (Zachariah, 2015).

Therefore, it can be argued that vertical hybrids, through their form, function, integration with technology, urban context and society seek to establish a "coherent balance of parts" emulating city environments, supporting flexible, mixed-use functions and incorporating green, accessible and porous urban networks (Per et al., 2014).

2.4. The Case of Singapore

Singapore is an urbanized, sovereign island-state with 5.61 million people on a limited land area of 718.3 square kilometers (Tobergte and Curtis, 2013). It presents a successful model of compact city planning with high-density, livable conditions for its citizens (Ministry of the Environment and Water Resources; Ministry of National Development (MND), 2009). The shortage of land and other resources have led to the intensification of the built environment over a period of 52 years since its independence. This has been made possible by the integrated planning efforts by various national agencies, headed by the MND, which directs the formulation and implementation of policies related to infrastructure development in the country. It importantly oversees the operations of the Urban Redevelopment Authority (URA) for land-use planning, the Housing Development Board (HDB) for public housing, the Building Construction Authority (BCA) for building infrastructure and the National Parks Board (NParks) for greening the environment. It can be reasoned that coordinated efforts between agencies negotiating the aforesaid requirements towards a comprehensive master plan have engendered the resultant urban environment with numerous hybrid developments (URA, 2016b). For example, mixed-use programming is widely encouraged by the URA to create "a vibrant and distinctive global city" through the introduction of "white sites", on which a range of uses can be included (URA, 2012). Privately-owned public spaces (POPS) are supported by regulatory means to

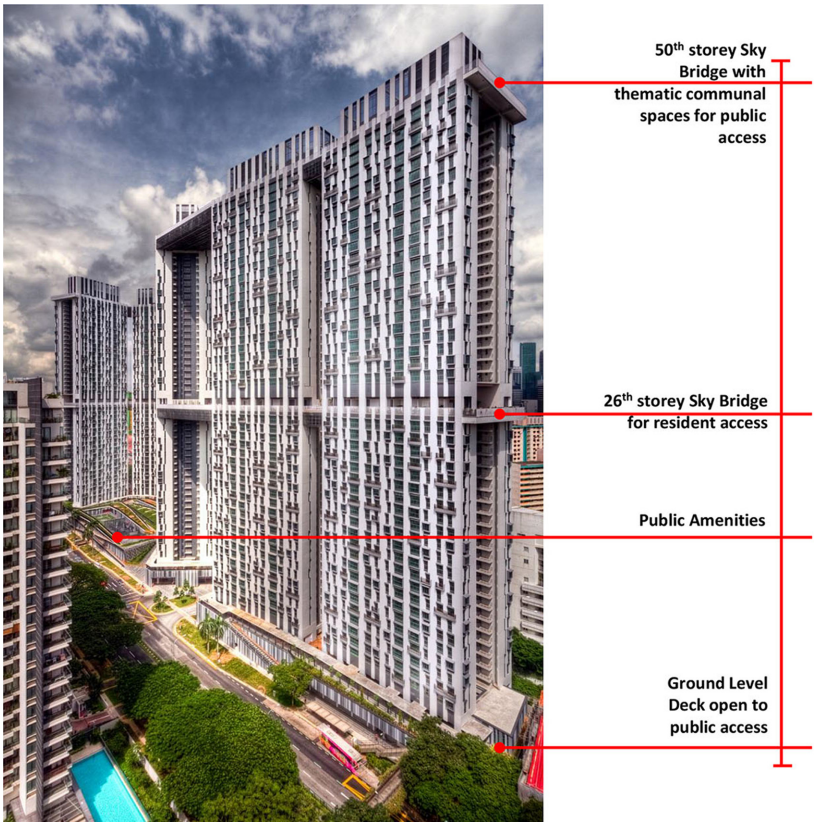


Figure 4. Pinnacle@Duxton integrating communal spaces within its built form (Credits: Wikimedia Commons).

include and improve public access, maximizing public space within the dense urban built environment (Urban Redevelopment Authority, 2016a). Envisioned as a "City in a Garden", some claim that "Singapore is the only city in the world to grow greener as it grows bigger, richer and denser" (Jencks, 2016). The URA works in coalition with building stakeholders to incorporate the Landscaping for Urban Spaces and High-Rises (LUSH) program to meet the regulatory requirements set by the Green Plot Ratio (GnPR) which provides incentives for the incorporation of sky-rise greenery.

These initiatives have led to notable projects such as *The Interlace* by Ole Scheeren, a residential "fabric hybrid" that presents an alternative spatial configuration to the vertical stacking of apartment units. Intended to create a unique sense of community living, the buildings form an interconnected mesh creating interstitial spaces for parks, public courtyards and the like (Davison, 2014), catering to the needs of 1,000 apartment units. *Pinnacle@Duxton* by ARC Studio and RSP is a pioneering high-density public housing project, an example of a "monolith hybrid", which provides a substantial volume of public, communal space on a tight, urban site (2.5 hectares) in downtown Singapore (Fig. 4). The building form serves to create porous ground-level public spaces complemented by a public podium and two skybridges on the 26th and 50th stories as "a form of compensation to detachments from the street level" while serving as connections between seven residential towers (Cho et al., 2016).

Learning Hub by Heatherwick Studio is an institutional "graft hybrid," which by form of its handmade concrete towers surrounding a central atrium interweaves porous ground-level public spaces with upper-level social learning spaces and informal garden terraces, creating a dynamic environment for casual and incidental interaction between students and academics.

Mapletree Business City II by DCA Architects is an office development akin to a "graft hybrid," which by its topographical stepped form, carves environmentally friendly urban spaces amidst its office towers.

Expanding on the novel typology of vertical hybrids and exploring new paradigms therein, three Final-Year Architectural Thesis projects at the National University of Singapore (NUS) address typological concerns associated with educational, office and housing land uses within Singapore.

3. Project Descriptions

3.1. *Learner's Paradise* by Heng Cheng Sin (Case 1)

"This project presents a case for a revolutionary vertical and compact university that uses a fraction of the land

Table 1. Comparative Study of campuses based on available site area and gross floor area allocation per student

Institution (Year)	Site Area	GFA/student
University of Cambridge (1209)	728 ha	18 sqm
National University of Singapore (1905)	150 ha	25 sqm
Malaysia University of Technology Petronas (1997)	400 ha	28 sqm
Mode Gakuen Cocoon Tower (2008)	0.52 ha	8 sqm
The Learner's Paradise (2017)	20 ha	30 sqm

Figure 5. The Learner's Paradise - site context and photos (Source: OneMap Credits: Heng Cheng Sin).

compared to typical university campuses worldwide to create a conducive and integrated living environment, which offers tripartite education encompassing community, industry and university" – Heng Cheng Sin

Sprawling higher-education campuses with disjointed faculty buildings and redundant social spaces (Harrison, 2012) are energy- and resource-intensive (Smith, 2013). A brief comparison of Gross Floor Area (GFA) per student in four universities shows a variance from 25 square meters/student in longstanding, suburban campuses to 8 square meters/student in modern, urban cases (Table 1) indicating space optimization in high-density urban settings. Furthermore, the importance of physical connectivity (via novel and various transport modes) that brings community and industries closer to academic environments, as well as facilitates cross and inter-disciplinary education, is significant and more recently recognised. Accommodating state-of-the-art e-learning and distance learning modes alongside traditional and didactic education methods also need to be considered.

The chosen site (20 hectares in area) is within the Jurong District in close proximity to the Nanyang Technological University, the industrial estates and public housing developments, and holds significant potential for the confluence of community, industry and university (Fig. 5). It abuts major roadways (Pan Island Expressway and Jurong West Ave 2) and a proposed Mass Rapid Transit (MRT) line for easy connectivity with the surrounding districts and green and blue natural elements that surround the site create opportunities for a salutogenic learn-live-work-play-make environment.

The Learner's Paradise, therefore, is envisioned as a transport-integrated campus with compact and dense built forms that are characterised by an assortment of shared, flexible spaces interpolated with green, social spaces, for innovative learning with a total GFA of 90 hectares for 15,000 students achieving 30 sqm per student, significantly higher than some others described in Table 1.

3.2. *Diversifying Workplaces* by Na Hsi-en (Case 2)

"The thesis proposes a mixed-use ecosystem for a vibrant, 24-hour active work environment with a future infrastructure appropriate for creating a synergy that will reinvigorate the CBD." – Na Hsi-en

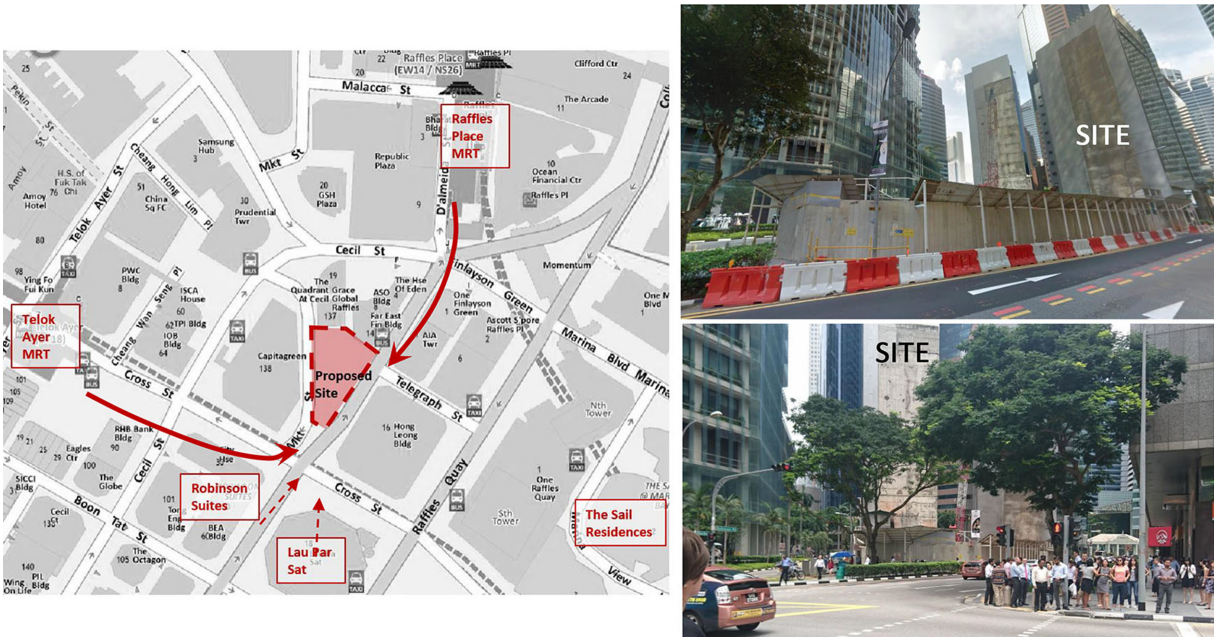


Figure 6. Diversifying Workplaces – site context and photos (Source: OneMap Credits: Na Hsi-en).

The traditional mono-use office development model with familiar vertical segregation of programs renders the existing CBD model incapable of providing for future working environments that warrant flexibility to support the 24-hour work culture (Ang, 2016) as well as spatial configurations in response to cross-disciplinary and collaborative work (Rifkin, 2014) within automated environments (Stefano, 2015). "Diversifying Workplaces" explores a new model of the CBD, devised to recuperate the large investment made in infrastructure and prime real estate value (Archibold and Chng, 2014), while importantly catering to the conveniences of the diverse workforce in-situ as well as those functioning remotely across different time zones afforded by technological and communication innovations (Ang, 2016). The site (0.2 hectares in area) is located at a junction between two arterial roads (Robinson Road and Cross Street) in the Central Business District of Singapore. Proximity to the two MRT stations (Fig. 6), presents an opportunity to improve connectivity with public transport nodes.

It seeks to repurpose and connect buildings around the chosen site, albeit within the given structural constraints, through injection of complementary functions and transport integration to support a "24-hour work culture". The proposal presents a novel office typology that supports four modes (focus, collaborative, social and learning) of working spaces and replaces redundant spaces with flexible spaces and circulation networks that could host different functions and users at different times of the day/week, thus extending their life and use, and introducing the concepts of time and space sharing.

3.3. *Hybrid Heartlands* by Javin Soh (Case 3)

"This thesis builds on the issue of resource scarcity in the built environment and makes a case for the replication of regenerative architecture of old public housing building stock, which aims to improve efficiency and reduce redundancies of programs and spaces in them." – Javin Soh

Being a land-scarce and resource-deficient nation, Singapore's building industry is heavily dependent on importing raw materials from neighbouring countries. "Hybrid Heartlands" challenges the Selective En bloc Redevelopment Scheme (SERS)[2] – a renewal approach that comes with unsustainable repercussions, as more extractions are carried out to meet the construction demands of new "relocation" housing, while existing functional resources are demolished (Soh, 2017). In doing so, the intrinsic values and associations embedded in these sites are also lost. The project argues that this can be avoided by sensitive repurposing of the existing buildings and introduction of various uses and amenities (with an emphasis on sociability) that cater to needs of the residents and the visitors (Cho et al., 2016). In doing so, it is possible to regenerate the older environments such that they become resource-efficient and humane.

The site (5.8 hectares) is located in Serangoon, a predominantly public housing district, in Singapore with a res-

[2]Older HDB estates are demolished and redeveloped as opposed to upgrading the existing flats via the Main Upgrading and Interim Upgrading Program

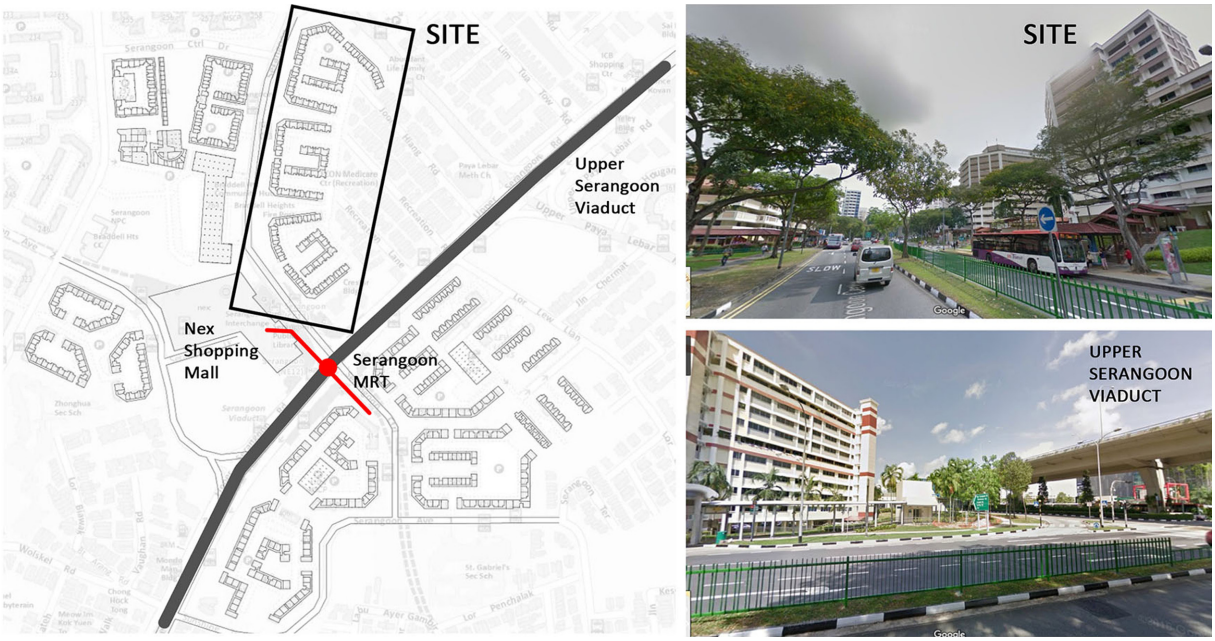


Figure 7. Hybrid Heartlands - site plan & photos (Source: OneMap Credits: Javin Soh).

idential population of approximately 73,000 people (Tobergte and Curtis, 2013). The site is bordered by the Upper Serangoon Viaduct, while the Serangoon MRT station and the NEX shopping mall provide links to the surrounding housing blocks (Fig. 7). The site includes 13-story housing blocks with a Plot Ratio of 2.8 to 3.0, which are typically considered as low-rise, medium-density blocks in the Singaporean context, and do not fulfil the rising demand of the growing population. Consequently these structures qualify for the SERS scheme.

This retrofit housing project borrows from and adds to the existing geometry, structure and layout of the existing buildings, so as to incorporate higher-ground networks amongst the blocks and provide a link below the viaduct that can integrate the estate with the neighbourhood. This is complemented by the introduction of mixed-use programs and amenities to create a thriving hybrid housing community that is resource-efficient, accessible, green and integrated with the transport infrastructure.

4. Analysis & Findings

This section highlights the commonalities in the three design schemes, illustrating the key features of "vertical hybrids", and points to the relevance and importance of a paradigm shift from "tall buildings" to "vertical hybrids" for the high-density urban context of Singapore.

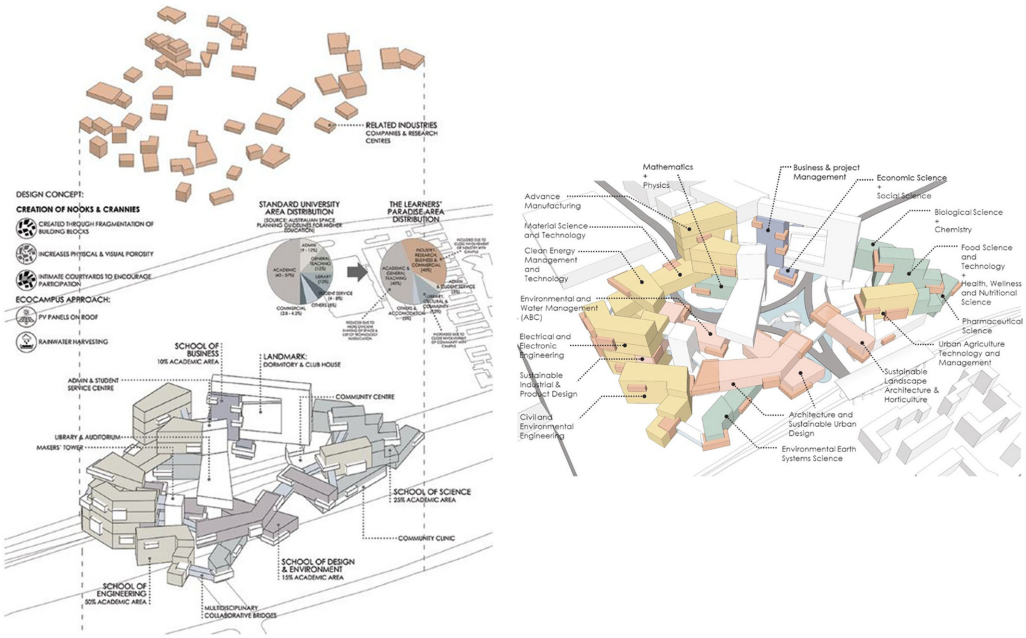
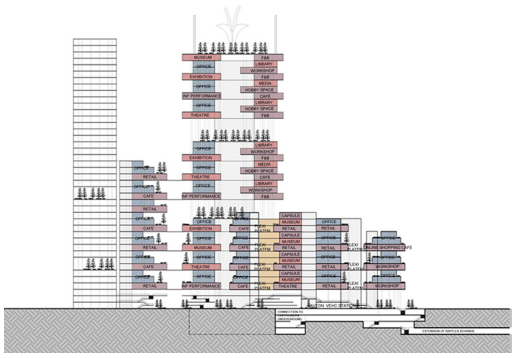
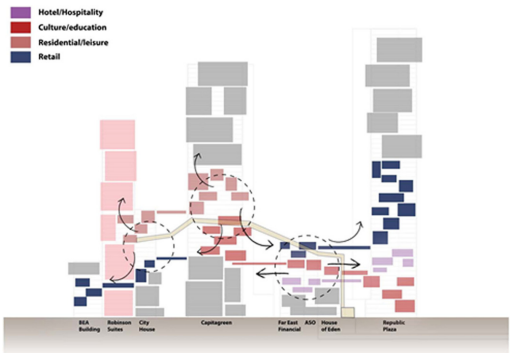
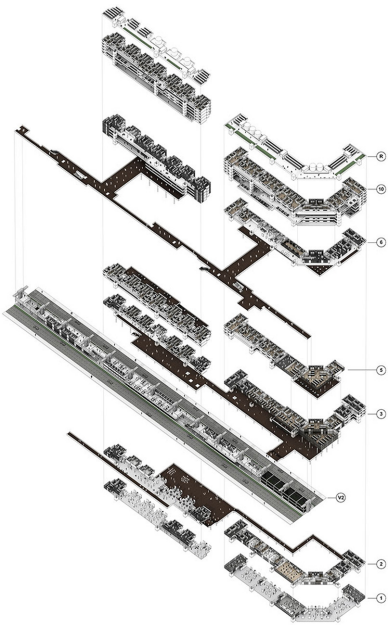
4.1. Form and Function of Mixed-Use Vertical Hybrids

Case 1 employs small-scale building blocks that are clustered based on the functional needs of industry-academia-community collaboration (Table 2(a)) and responds to the urban grain, similar to the "fabric hybrid" typology described by Fenton (1985). Case 2 merges office, commercial, hospitality, culture, educational and retail functions within a unifying building form, owing to structural and contextual constraints of the site, indicative of the "monolith" hybrid (Fenton, 1985) that responds to dense, urban contexts. Here, staggered blocks with the carving of public and semi-public spaces and sky-bridges enable the incorporation of different use and functionalities (Table 2(b)) under one roof to make these developments vibrant and liveable and ensuring sufficient concentration of people (Jacobs, 1961) across different demographics and interests. Case 3 refines the building form within the structural constraints of the existing development and the adjacent viaduct akin to the "graft" hybrid (Fenton, 1985), to create a vertical neighbourhood comprising educational, tourism, healthcare, retail, commercial, F & B, offices and community amenities (markets) (Table 2(c)).

The three cases, through their common approach, evidence a marked shift in the built character from traditional, monolith tall buildings to porous blocks connected via vertical and horizontal spatial elements like skybridges, decks, sky lobbies or staircases that make comprehensive links within the development and with the surrounding buildings, infrastructure and transport. Amongst others, *Vanke Center*, Shenzhen, China, by Steven Holl is one such example, reinterpreting the skyscraper as a horizontal entity ingrained into the context with ground and elevated movement corridors for public access.

Additionally, the fragmented and staggered building masses create permeable edges that may lead to multiple choice of routes and unconventional in-between spaces

Table 2. Fragmentation of Built Form in response to urban context, functional needs and site constraints

Learner's Paradise (a)	
Diversifying Workplaces (b)	 
Hybrid Heartlands (c)	 

(Carmona et al., 2010) that can support various forms of collaborations and interactions (Fig. 8) and improve sociability within these environments.

Furthermore, it can be argued that the development of

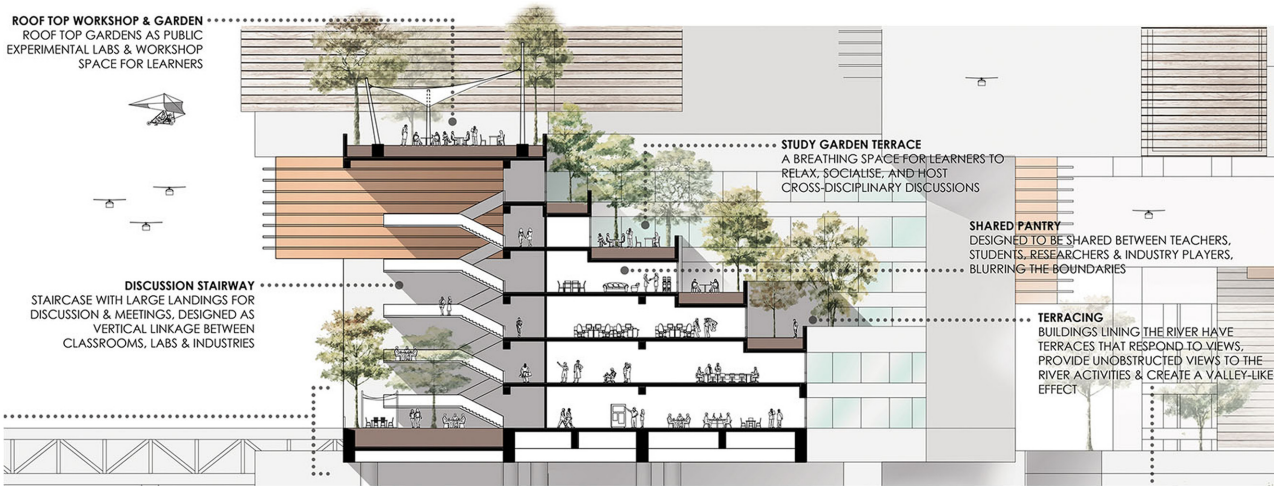


Figure 8. The Learner's Paradise showcases corollaries of semi-open spaces breaking the mass of adjoining classrooms that serve as connecting social spaces, rendering the building mass into a breathable, green and humane entity (Credits: Heng Cheng Sin).

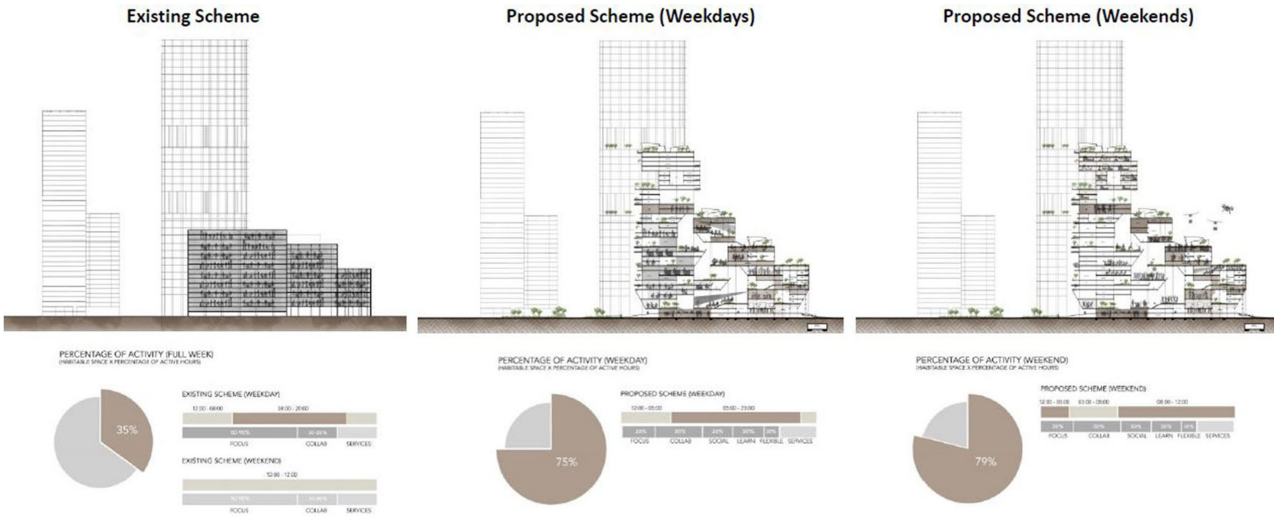


Figure 9. Diversifying Workplaces illustrates the impact of the injection of mixed-use within the mono-functional CBD in terms of improving the level of activity over weekdays and vibrancy over weekends (Credits: Na Hsi-en).

the fragmented building form and the interstitial open, flexible and green spaces can be attributed to the injection of mixed-use programs and lead to spatial efficiencies.

Theoretically, these mixed-use environments represent one primary function, around which other programs derive their relevance within the urban context. For example, "Diversifying Workplaces" (Case 2) (Fig. 9) suggests that the retail and cultural spaces along the horizontal spine across buildings importantly creates an inclusive environment with dynamic movement of people and activates the buildings, unlike the typical mono-use office towers.

Similarly, *Tokyo Midtown,* comprising commercial, hotel, museum and leisure programs within a cluster of towers, fuels the movement of people from surrounding streets and sidewalks via major view corridors, bridges, and plazas, creating a sense of "interconnectedness" across the various buildings.

The three projects evidence that advances in technology, such as online teaching and smart classrooms (Case 1), building automation, and cloud computing (Case 2), demand certain spatial variations and flexibilities that support time/space sharing, and seemingly characterize the hybrid environments, while ensuring resource efficiencies, density of uses and users, and humanization of these gigantic environments. (Fig. 10).

Figure 10. "Diversifying Workplaces" showcasing space sharing over weekdays and weekends powered by technological advancements (Credits: Na Hsi-en).

4.2. Integrating Multi-Level Access and Transit Integration

In Case 1, the fragmented, clustered building forms (Section 4.1.) create "nooks and crannies", "collaborative learning bridges", courtyards and plazas for various activities to bridge different uses, programs and disciplines (Table 4(a)). This is augmented by an elevated "Mobility Corridor" which connects Case 1 with the proposed MRT station and surrounding developments in a looped network. This elevated corridor loop has transit nodes that are positioned strategically within each cluster to enable a seamless transition into the buildings.

Case 2 employs elevated sky decks that extend street infrastructure into the vertical realms, through the introduction of bridges, which effectively inject new pedestrian movement patterns onto the higher levels, blurring the boundaries between the developments within the CBD (Table 4(b)). At grade, it proposes reduced road widths, to accommodate only public transport and autonomous vehicles;[3] this is supported by extensive linkages to the below-ground MRT network (Table 6(b)). The reduced roads make way for bicycle- and pedestrian-friendly trails on the ground level, connecting culture, retail, leisure and hospitality spaces. The ground and elevated networks together seek to engender a novel, integrated CBD environment.

The viaduct link in Case 3 (Section 3.3.) with surrounding buildings and the MRT station enables effective segregation of pedestrian traffic from the vehicles (Table 4(c)). The project uses its underside to create a secure pedestrian link between the housing blocks and neighboring housing developments, the MRT and the NEX mall. This link, essentially a new piece of infrastructure, brings to life a redundant and undesirable "undercroft" space, through the incorporation of a market, small workshops, retail and community functions.

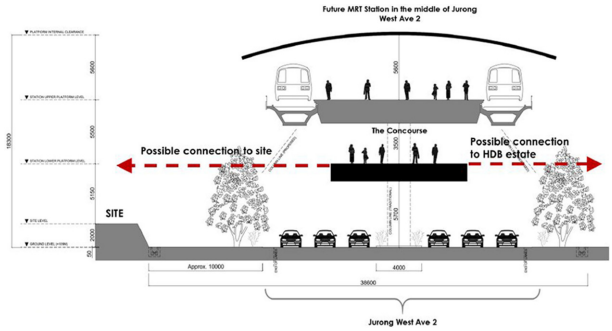
All three cases present opportunities for promoting social interaction by adjacency to transitional spaces, various points of ingress and egress and multiple mobility modes. Importantly, they highlight the importance of creating fine-grained networks of multiple modes of transit and their holistic integration within and between developments. Furthermore, these networks do not serve merely as conduits for movement, but rather are populated with different uses that activate them and make them safe. Provision of dedicated elevated mobility corridors, along with strategic nodes and incorporation of various functions, may enable smooth transitions and promote novel transactions between various uses within mixed-use developments. This approach, however, requires more of a large-scale systems-thinking approach and a coordinated effort across different agencies within a city.

It can be therefore assumed that carefully calibrated higher-ground networks can present opportunities to generate taxonomies of flexible spaces that have the potential to activate the upper reaches of mixed-use environments, generate revenue, provide "natural surveillance" and bring amenities to the doorstep, and in doing so, tie the vertical environments more strongly to the horizontal city. The transitions from the ground plane into the upper reaches of the buildings through a matrix of public/semi-public spaces are also evident in built examples, such as the *Jianwai SOHO* in Beijing by Riken Yamamoto.

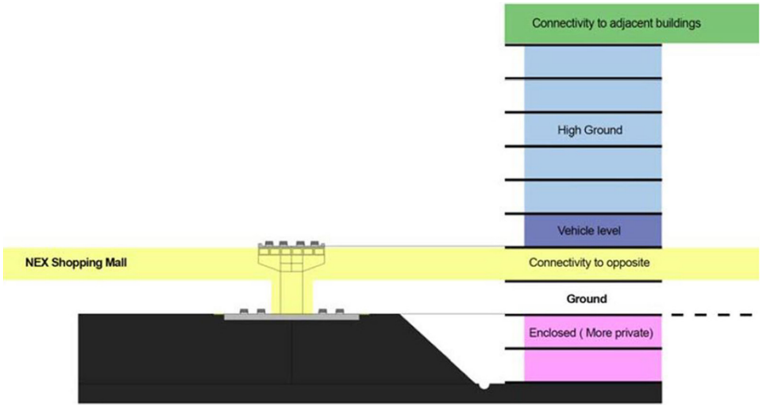
The three cases acknowledge that although the primary component of user movement is the ground plane, the verticality of the buildings may require effective and extensive below- and higher-ground networks. Visible segregation of pedestrianized and non-pedestrianized movements (Salingaros 1999), aided by such elevated or underground transport networks, can free up the ground plane

[3]that typically increase road capacities by 273% (Tientrakool, Ho, and Maxemchuk 2011).

Table 3. Multi-Level Access & Transit Integration

Learner's Paradise (a)	Diversifying Workplaces (b)
	

Hybrid Heartlands (c)



for safe and successful public places and greening, promoting healthier lifestyles through walking and cycling, and using cleaner modes of transport. Finally, as evidenced by the cases, multi-modality can provide travel options for a large volume of commuters, which in turn can aid efficiency in commute time, distance and costs. For example, *The IFC-Exchange Square*, Hong Kong connects several buildings via elevated pedestrian decks, while also being integrated with the Mass Transit Railway (MTR) System underground.

4.3. Provision of Green and Social Spaces

Staggering of the built form and edges (Section 4.1.) to carve out green and transitional spaces in Case 1 and Case 2 introduces accessible greenery in the upper reaches of a building that may contribute towards stress-relieving, restorative and salutogenic settings, critical in the context of dense, tall urban settings (Gifford, 2011). In Case 3, green features also take the form of outdoor/semi-outdoor sky decks, sky gardens and community gardens that support a multitude of community activities and become democratic spaces that can be inhabited and managed by the residents (Table 5). This is also evidenced in Case 1 and 2, in which the elevated green spaces offer important opportunities for collaboration, learning and encompassing other complementary uses.

Perforations in the built form, via pocket gardens, sky-bridges and planters, soften the otherwise perceived harshness of the typical, glazed and sealed high-rise environments, while offering shaded green spaces as a respite from tropical weather conditions.

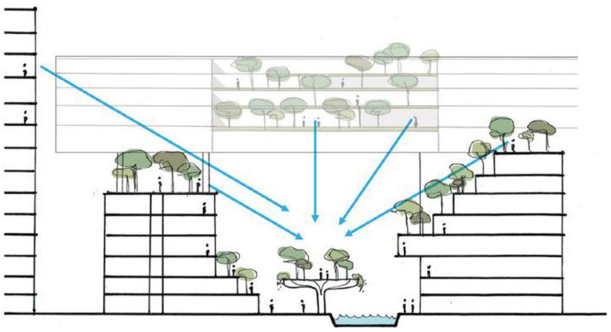
Furthermore, apart from serving as important nodal points for improving sociability in urban environments, green spaces in vertical hybrids would help reduce urban heat island effects, improve air quality, stormwater management and biodiversity, and energy efficiency in buildings. *Punggol Waterway Terraces* in Singapore is a public housing development with building-integrated greenery, articulated by its green terraced built form, to serve myriad environmental benefits, while providing users with an experiential connection to the landscape and the neighborhood. Importantly, urban green spaces, at grade and within the vertical environments, humanize the otherwise dense urban settings, and in doing so, create important breathing lungs within our cities.

5. Conclusion

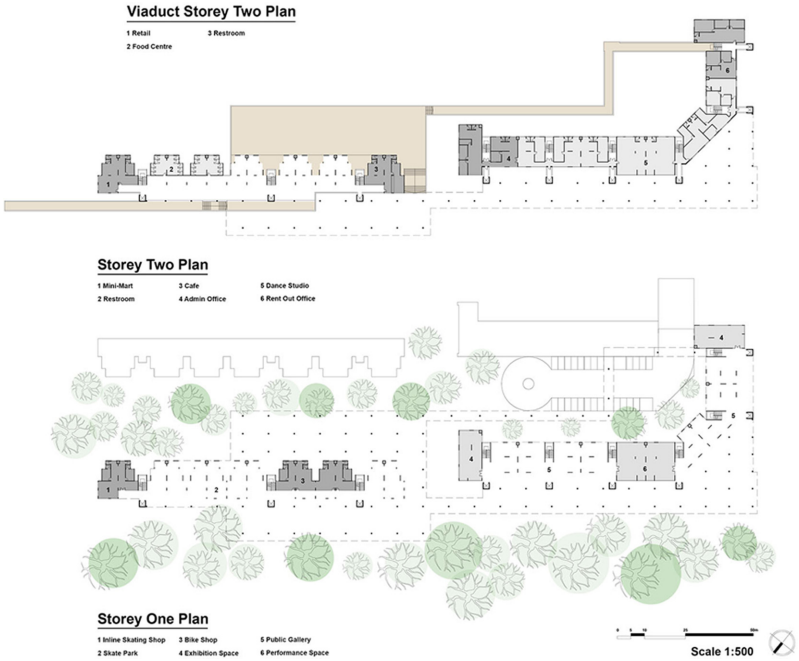
In the context of increasing urban densities and associated pressure on urban land and the built environment, this paper examines how vertical cities could be dense, resource-efficient and yet humane, through the "vertical hybrid" model.

The tall building typology is constantly evolving in res-

Table 4. Green/Democratic Spaces

Learner's Paradise (a)	Diversifying Workplaces (b)
	

Hybrid Heartlands (c)



ponse to the need for dynamic integration of live-work-play-learn-and-make programs, leading to the concept of "hybrid" buildings. Embedding large-scale hybrids within a high-density context requires careful consideration of the urban grain, so as to not obliterate city connections (physical and visual) and erode urban morphology. This suggests the need for a sensitive approach that breaks down verticality through smaller masses interspersed with a certain porosity, as well as horizontal and vertical linkages between buildings, and integration with transit infrastructure. This should be accompanied by a system of varied social and green spaces (skybridges, sky decks, sky gardens etc.) that can potentially encompass a diverse range of functions and support space-sharing and time-sharing, so as to reduce redundancies in our urban environments. These spaces, when integrated with transit networks, will activate the upper reaches of the development and improve transitions between the vertical and horizontal components of a city. The resultant fluidity, it is argued, would improve spatial efficiencies, natural surveillance and vibrancy of urban environments.

On an urban scale, integrating hybrid buildings with transit-oriented infrastructure would reduce reliance on the use of personal vehicles such as cars and promote clean modes of transport. This, of course, would have implications for the development of city-level infrastructure and urban planning and would require a systems approach and coordinated efforts by multiple agencies.

While the significance of the ground plane is not undermined, there is a shift in emphasis towards carefully calibrated higher-ground networks, comprising taxonomies of congregational/green spaces that would ameliorate vertical stratification within tall buildings. The increased use of public transport and autonomous vehicles would reduce the domination of cars and roads, and allow for greener environments suitable for walking and cycling, and promote healthier urban living. Moreover, integrating various modes of transport vertically, and the emphasis

on pedestrian-friendly design and activated street fronts on the ground, would enhance the economic viability and sociability within mixed-use developments.

Spatial typologies like sky gardens and sky decks would increasingly bring urban population closer to nature, while also democratizing the vertical environments that would improve urban sociability and well-being, and improve the health of our cities. The design strategies adopted in the three projects importantly showcase possible trajectories for contemporary hybrid developments that may lead to dense, resource-efficient and yet humane urban environments.

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