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Regulating Natural Lighting and Ventilation of Residential Buildings in Hong Kong
Policy Implications for High-rise, High-density Housing Environments in South Korea

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Abstract This study discusses the features of the lighting and ventilation regulations for residential buildings in Hong Kong. Given the compact built environment and public concerns about the environmental quality of housing, various lighting and ventilation regulations have been enacted in Hong Kong. The application of building regulations on the micro scale and incentive systems on the macro scale are present, and the governments' calls for more active participation of the private sector and use of the building environmental assessment tools were also noted. Unlike South Korea, however, Hong Kong was found to adopt more performance-based standards, consider the external factors of the lighting and ventilation conditions together with the indoor elements, and provide specific design guidelines. Notwithstanding the different climatic conditions and socio-political contexts of Hong Kong and South Korea, these findings provide some policy implications for the South Korean government in its efforts to achieve a healthy environment for high-rise, high-density housing. It is suggested that the South Korean government adopt more on-site measurement methods to reflect the environmental conditions accurately and broaden the scope and scale of the implementation of the lighting and ventilation regulations with more specific, practical planning and design guidelines.

Keywords: Lighting, Ventilation, Healthy Housing Environment, South Korea, Hong Kong

1. INTRODUCTION

Hong Kong has gone through rapid urbanization and densification due to the immense influx of population since the mid-1940s (Zhang, 2000). Given the limited land resources, high-density development has been unavoidable in order to accommodate the ever-growing population. In most of the urbanized areas, housing estates are mostly about forty to fifty storeys high, and have a plot ratio of 5 or above[1] (Hong Kong Planning Department, 2011).

The compact urban form in Hong Kong has often been associated with public hygiene problems. Specifically, the decreased wind speed and lack of natural sun light due to the high density were believed to bring about the poor air quality in the urban areas (Hong Kong Government, 2007). The lack of natural ventilation in a compact residential building complex also exacerbated the indoor air pollution (Lee et al., 2002). Amid the general concerns about the impact of the compact built environment on public hygiene, the outbreak of SARS in 2003 has facilitated building a consensus of the necessity for high-density housing to become healthier and more comfortable (Wong, 2010).

This study aims to examine the policy to ensure an adequate level of natural lighting and ventilation in super high-rise housing developments in Hong Kong in view of a healthy housing

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[1] Statutory development density (maximum plot ratio) according to zoning plan in Hong Kong and South Korea

Hong Kong	South Korea
High density zone (Existing development area): 7.5-10 High density zone (New development area and Comprehensive development area): 6.5 Medium density zone: 5 Low density zone: 3	Residential zone: 5 Commercial zone: 15 Industrial zone: 4 Green zone: 1

Source: HKSAR Planning Department (2011), Korean Ministry of Land, Infrastructure and Transport (2013b).

environment. The Hong Kong government has strived to enhance the natural lighting and ventilation conditions of buildings in various ways. Considering the increasing public concern on the indoor environmental quality of super high-rise housing in South Korea (See, for example, Baik and Kang, 2005; Kim and Lee, 2005), the findings of this study also provide some insights for recommending guidelines for the lighting and ventilation regulations in South Korea in the end.

This paper consists of four parts. First, it presents a brief overview of the high-rise housing features in Hong Kong and South Korea and demonstrates the circumstances in which Hong Kong and South Korea have tried to attain a healthy built environment in high-rise and high-density housing developments to help better understanding of further discussion. Next, it analyzes the current building standards and regulations in Hong Kong with particular regard to natural lighting and ventilation in residential buildings and illustrates two housing development cases as examples. Then, it discusses the implications of the Hong Kong case for policy implementation to achieve a healthy environment in high-rise, high-density housing in South Korea, if any. Finally, conclusions are drawn.

2. THE FEATURES OF HIGH-RISE HOUSING AND GOVERNMENT EFFORTS TO ENSURE A HEALTHY HOUSING ENVIRONMENT IN HONG KONG AND SOUTH KOREA

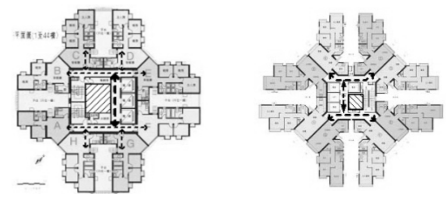
(1) The High-Rise Housing Features in Hong Kong and South Korea

In South Korea, the dominant housing form in major cities has changed from detached houses to apartment buildings which currently account for 59% of total housing units (Statistics Korea, 2010). The maximum statutory plot ratio for residential development in urban areas is 15. In Seoul, the plot ratio of some of the high-rise mixed use residential developments is usually over 5 or 6 (Kwon et al., 2005).

Super high-rise residential buildings are very common in Hong Kong. According to Jeong et al. (2005), there are far more super high-rise apartments in Hong Kong (920 buildings) than in South Korea (76 buildings). In both regions, super high-rise apartments are usually 45 to 50 storey mixed use tower-shaped buildings. However, while super high-rise apartments in Seoul tend to be mixed with offices, those in Hong Kong usually have amenities for the residents (e.g. club house, sports facilities, etc.) and commercial facilities open to non-residents (Jeong et al., 2005).

The housing block forms vary from rectangle, T-shape, trident to cruciform type. However, housing units in high-rise residential buildings in Hong Kong, unlike those in South Korea, tend to have projecting windows[2] and many re-entrants which maximize the use of interior spaces and increase the surface of the external walls facing into the open air (Figure 1 and 2).While super high-rise housing in Hong Kong is usually developed in the form of housing estate comprised of a few housing blocks, they tend to stand alone as a single block in South Korea (Jeong et al., 2005).

[2] Projecting window is a typical residential window design in Hong Kong, referring to the window area extruding from the inner space.



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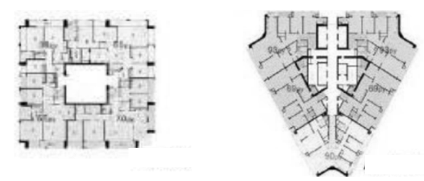


<South Korea>

Figure 1. Typical floor plans of super high-rise housing
Source: Kim and Kim (2007), Kim and Lee (2005)

Figure 2. A projecting window in Hong Kong
Source: Authors

(2) Governments' Efforts for a Healthy Environment in High-Rise and High-Density Housing

In response to the rising public concern on building environmental quality, the Chief Executive in Hong Kong announced a policy directive entitled 'quality city and quality life' in his Policy Address and emphasized improvement of the urban environmental quality through tightening the building density regulations, so that people can enjoy more fresh air and natural light (Hong Kong Government, 2007). The Buildings Department also amended the building regulations to encourage developers to incorporate more green ideas into their residential projects. In addition, from 2006 the Planning Department began to assess the impact of major government (re)developments on the air quality of the surrounding environment.

The Hong Kong Housing Authority and the Hong Kong Urban Renewal Authority have cooperated to improve the hygiene and safety conditions of the old residential buildings by conducting extensive maintenance programs. In addition, the building environmental assessment tools, such as the Hong Kong Building Environmental Assessment Method (HK-BEAM) and the Comprehensive Environmental Performance Assessment Scheme for Buildings (CEPAS), have also been used to assess the hygiene, health, safety and amenity aspects of residential buildings (Table 1).

In South Korea, an adequate indoor environmental quality for super high-rise housing has not always been ensured. Coupled with the global trend towards sustainable development in the 1990s, the deteriorating natural lighting and ventilation conditions of high-rise, high-density housing have stimulated discussion on the ways to realize a healthy environment in residential buildings under much broader concepts, such as 'Environment-friendly housing,' 'Well-being housing' and 'Ubiquitous housing.' A number of studies have been conducted focusing on the factors of the healthy housing environment, residents' satisfaction of or needs for their homes with regard to the health issues, and the performance standards for desirable indoor environmental quality (See, for example, Lee et al., 2005; Kim et al., 2008; Lee and Lee, 2008).

Being aware of the necessity for the assessment system to promote a healthy environment in high-rise, high- density housing, the South Korean government promulgated the 'Clean and Healthy Housing Construction (CHHC) Standards' in 2010 and tried to safeguard the adequate indoor air quality of housing (Korean Ministry of Land, Transport and Maritime Affairs, 2010) (Table 1). In 2013, it also introduced the 'Green Building Certification System (GBCS)' and has administered the green building assessment system in cooperation with a non-government organization. The large development companies have also tried to incorporate more environment-friendly elements in their housing projects so as to attract potential homebuyers who are concerned about health and environmental issues.

3. BUILDING REQUIREMENTS FOR NATURAL LIGHTING AND VENTILATION OF RESIDENTIAL BUILDINGS IN HONG KONG

(1) Building Regulations and Incentive Systems

Given the governments' efforts to achieve a healthy environment in high-rise, high-density housing, building regulations and requirements to enhance the lighting and ventilation standards have been developed in Hong Kong. Table 2 presents the mandatory building regulations and advisory building requirements of Hong Kong, including the certification systems, with particular regard to natural lighting and ventilation of residential buildings. In this section, the features of these standards are analyzed.

First, most of the mandatory requirements are strictly regulated by the Building Regulations under the Building Ordinance on the room or flat scale, particularly concerning the size of windows both for lighting and ventilation and whether the windows face directly into the open air; but on the housing block and housing estate scale, the requirements tend to be promoted by the government incentive systems rather than by building regulations. It seems that the Hong Kong government intends to allow developers flexible design strategies on the macro scale, while safeguarding the minimum level of indoor environmental quality on the micro scale.

Second, the Hong Kong government promotes a progressive engagement of the private sector by offering various development incentives that incorporate 'green' ideas into the housing projects. It exempts the environment-friendly features of a project from the gross floor area (GFA) calculations and gives GFA concessions to the developments complying with the sustainable building design guidelines. Such incentive systems indicate that the government is well aware that the voluntary participation of the private sector is the key for successful policy implementation to achieve the healthy environment in high-density housing.

Third, the use of the building environmental assessment tools, namely HK-BEAM and CEPAS, is encouraged. While HK-BEAM

Table 1. Building Environmental Assessment Tools in Hong Kong and South Korea

Category	Hong Kong		South Korea	
	HK-BEAM	CEPAS	CHHC Standards	GBCS
Assessment categories	- Indoor Environmental Quality (IEQ) - Site Aspects - Energy Use - Water Use - Material Aspects	- Indoor Environmental Quality (IEQ) - Building Amenities - Loadings - Site Amenities - Neighborhood Amenities - Neighborhood Impacts - Site Impacts - Resources Use	- Use of environment-friendly household items - Use of environment-friendly building materials - Ventilation equipment performance - Environment-friendly construction methods	- Indoor Environmental Quality (IEQ) - Management and Maintenance - Land Use and Transportation - Ecological Environment - Energy and Prevention of Environmental Pollution - Building Materials and Resources - Water Circulation and Management
Implementer	Non-government organization (BEAM Society)	Government (Buildings Department)	Government (Ministry of Land, Infrastructure and Transport)	Government (Ministry of Land, Infrastructure and Transport, Ministry of Environment), Non-government organization (Korea Institute of Construction Technology)
Target building	All types of buildings (Existing and New buildings)			New development and remodeling of housing (1000 units≤)
Features	- Emphasis on IEQ - Labeling system			
	- Comprehensive assessment - Prerequisite for GFA concession application	- Comprehensive assessment - Considering the impact on surrounding environments	- Focus on building materials - Incentives on house selling prices	- Comprehensive assessment - Concessions on GFA, building heights and green areas - Financial support and tax exemption

Sources: Hong Kong Buildings Department (2006), HK-BEAM Society (2012), Korean Ministry of Land, Infrastructure and Transport (2013a) and Korean Ministry of Land, Transport and Maritime Affairs (2010).

Table 2. Building requirements for lighting and ventilation of residential buildings in Hong Kong

Category	Items	Scale
Mandatory	BR[1)]29, 30 Lighting and ventilation: general introduction Lighting and ventilation of rooms used or intended to be used for habitation or as an office or kitchen: Minimum size of windows (1/10 of floor area for lighting, 1/16 for ventilation) (alternatively, APP[2)] 130 Minimum level of VDF[3)] and ACH[4)])	Room, Flat
	BR 31 Conditions of the 'external air' faced into by the windows BR 32 Restriction on distance any part of room may be from prescribed window: Maximum depth of a room from the windows (9m) BR 33 Windows opening on to enclosed verandah, etc. (compliance with BR 30 and 31) BR 35 Additional ventilation required for rooms with inadequate natural ventilation BR 36 Rooms containing soil fitments: Minimum size of windows (1/10)	Room
	BR 37 Light and air not to be diminished by new buildings	Flat
	Air Ventilation Assessment (AVA) Impact of a particular building on the ventilation of surrounding buildings (applicable to major government (re)development projects)	Housing block, Housing estate, Neighborhood
Advisory	JPN[5)] 1 Exemption of green and innovative features from GFA and/or SC calculations for balconies, wider common corridors and lift lobbies, communal sky gardens, acoustic fins, wing walls, wind catchers and funnels JPN 2 Exemption of green and innovative features from GFA and/or SC calculations for utility platforms (similar to air conditioning platforms) and widened mail delivery rooms with mailboxes	Housing block
	APP151 Building design to foster a quality and sustainable built environment (general) APP152 Sustainable building design guidelines (detail) - Building separation, building set back, site coverage of greenery - GFA concessions (overall cap 10%, BEAM Plus assessment report required)	Housing block, Housing estate
	HK-BEAM Partly assessing indoor environmental quality of hygiene, indoor air quality, ventilation, thermal comfort, lighting quality	Room, Flat, Housing block, Housing estate, Neighborhood
	CEPAS Partly assessing indoor environmental quality of health and hygiene, indoor air quality, lighting environment	

Sources: Extracted from Hong Kong Buildings Department (2006), Hong Kong Planning Department (2011), HK-BEAM Society (2012)
Notes: [1)] BR: Building Regulations, [2)] APP: Part of the former Practice Note for Authorized Persons, [3)] VDF: Vertical Daylight Factor, [4)] ACH: Air Change per Hour, [5)] JPN: Joint Practice Note

is developed and implemented by the non-profit organization, CEPAS is administered by the government. Developers are required to submit the assessment report to the government in order to obtain the development incentives. Among the assessment criteria, the elements with regard to the indoor air quality are generally given more weight than other criteria. Therefore, these assessment tools play an important role in regulating the lighting and ventilation conditions, in that the government suggests objective standards that help practitioners meet the government requirements.

Forth, the performance-based standards are emphasized. The Hong Kong government has recently suggested alternative standards regarding lighting and ventilation, namely, the minimum Vertical Daylight Factor (VDF)[3] (Figure 3) and Air Change per Hour (ACH), instead of the minimum size of windows. With regard to the regulations for lighting, not every housing unit can have sufficient direct sunlight because of the heights of surrounding buildings in Hong Kong (Ng, 2003). Therefore, it is impractical to apply the same rule of window sizes regardless of the building height. In this regard, the Hong Kong government tries to take into account the actual daylight conditions of different floors in regulating lighting standards by using the Unobstructed Vision Area (UVA) method[4].

The AVA also employs several computational simulation models.

[3] The VDF required for habitable rooms is 8%, and 4% for kitchen. This requirement was suggested in 2003 by Professor Edward Ng at the Chinese University of Hong Kong. In developing these standards, a computational simulation method combined with a user survey was employed. See Ng (2003) for more details.

[4] The UVA tool was developed based on the assumption that the source of the natural lighting at the lower floors in high-rise, high-density environment is mostly reflected light from the surrounding buildings. Thus, UVA is speculated as 'an aggregated horizontal open area in front of the window which is a cone with the horizontal angle of 100 degrees centered to the normal of the glazing.'

$UVA = kH^2$

k: constant (higher if the VDF required is higher)

H: Building height (m)

Thus, if the height of building façade is higher, the UVA should also be larger. See App130 (Hong Kong Buildings Department, 2010) and Ng (2003) for more detailed explanation of applying this method.

In addition, the building performance tools, such as HK-BEAM and CEPAS, partly apply some performance-based standards with regard to the indoor environmental quality of buildings. This implies that the Hong Kong government endeavors to reflect more precisely the contextual conditions in regulating natural lighting and ventilation of residential buildings.

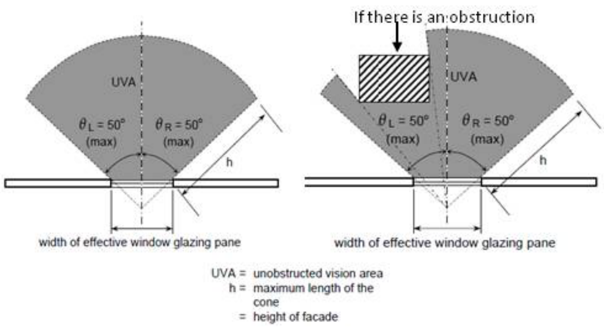


Figure 3. Measurement of the cone of UVA
Source: Hong Kong Buildings Department (2010)

Fifth, with regard to the indoor air quality and ventilation aspects, the outdoor air quality is also taken into account in Hong Kong. While the building regulations and building performance assessment tools mainly relate to lighting and ventilation at the housing unit scale, the housing block and housing estate level issues are also substantially embodied in JPN1/JPN2 and APP151/APP152, which appear to have contributed to addressing the development site conditions in a holistic manner. Although CEPAS concerns indoor sources of air pollution to some extent, most of the building requirements to improve the indoor air quality relate to the housing block, or housing estate, scale design and the installation of necessary ventilation equipment.

These measures are based on the government's awareness that the compact, bulky housing block design has adversely affected the outdoor air flows at the pedestrian level, consequently decreasing the natural ventilation of indoor spaces (Hong Kong Government, 2007). In order to enhance the air flow, the Hong Kong government has implemented the Air Ventilation Assessment (AVA) and tightened up the regulations for design methods which have contributed to the compact housing block design[5].

In terms of the room or flat scale, the design to ensure appropriate cross ventilation is a statutory requirement in Hong Kong. For example, the maximum depth of a room from the primary opening stipulated in BR32 can be relaxed from 9m to 12m if a secondary opening is properly provided for in the room (Figure 4).

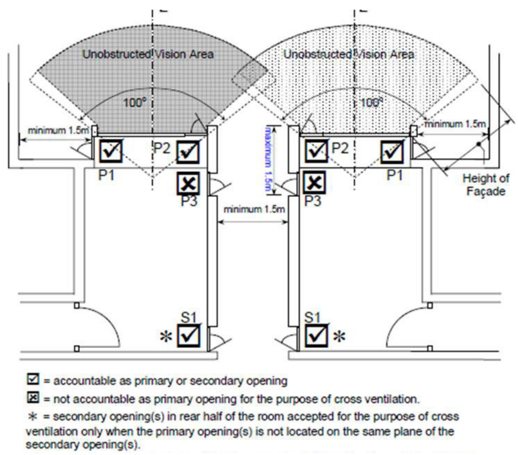


Figure 4. Requirement regarding cross ventilation in Hong Kong
Source: Hong Kong Buildings Department (2010)

Finally, the Hong Kong government tends to provide very specific guidelines on the planning and design strategies to enhance natural lighting and ventilation. The government encourages developers to use environment-friendly features in their plans, such as balconies, wider corridors, communal sky gardens and ventilation equipment. This measure is stipulated in JPN1 and JPN2 which interpret how these green features should be applied in the design[6]. In addition, according to the Sustainable Building Design (SBD) Guidelines, three major planning and design strategies[7] to enhance the air flow are specified in APP151 and APP152 which provide detailed explanations of how the requirements can be measured and realized in practice (Figure 5).

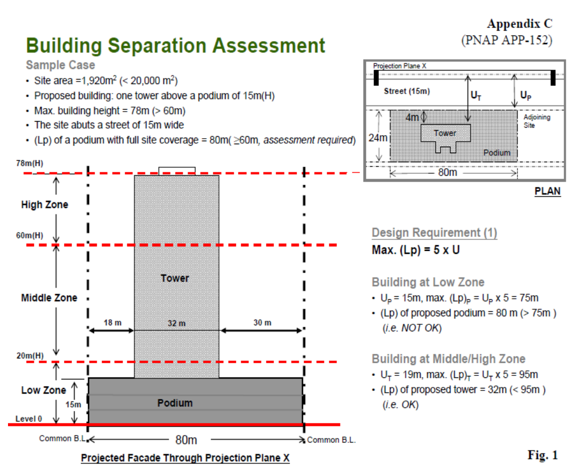


Figure 5. Sample case drawing and interpretation
Source: Hong Kong Buildings Department (2011)

5 For example, the Hong Kong government has recently reduced the maximum depth of projecting windows allowed in residential developments from 500mm to 100mm. Since projecting window areas have been included in saleable areas, but excluded from GFA calculations, developers used to maximize the depth of projecting windows to gain more profits, which consequently contributed to the bulkiness of housing blocks.

6 In JPN1, for example, the design strategies of the green features explained in 14 items for 'Balconies for residential buildings,' 5 for 'Wider corridors and lift lobbies,' 16 for 'Communal sky gardens in residential buildings' and 8 for 'Wing walls, wind catchers and funnels,' together with the reference drawings.

7 ①Building separation: permeability of buildings 20 - 33.3% ②Building set back: street canyon area of 15m x 15m ③Site coverage of greenery: 20-30% (site areas of 1000m² or more)

(2) Case Studies

The new building regulations and planning recommendations with regard to daylight and natural ventilation have been embodied in many housing projects since the 2000s. They have tended to be applied more actively to the government (re)developments as exemplary cases for private developments. This section illustrates two development cases which reflected well on the new building requirements in the planning and design process. These brief case studies will provide better understanding of the modes of application of the building regulations for better natural lighting and ventilation in Hong Kong's housing. The selection of the cases was made based on the relevance of the project to our discussion and the availability of the development information.

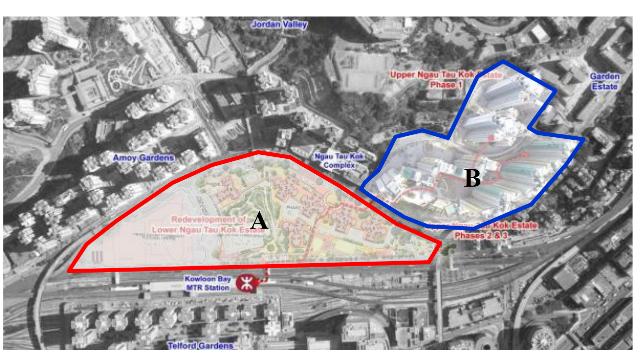
① Ngau Tau Kok (NTK) Estate redevelopment

Ngau Tau Kok Estate is located in Kwun Tong District, one of the most densely populated areas in Hong Kong. It is currently comprised of two parts – Upper Ngau Tau Kok (UNTK) Estate and Lower Ngau Tau Kok (LNTK) Estate. The area was developed in 1967 by the Hong Kong Housing Authority for resettlement. As the estate had been seriously dilapidated, the HKHA decided to redevelop the area with a better quality housing environment. While UNTK was redeveloped in 2009, the redevelopment of LNTK was completed in 2012. It is because the newly developed UNTK estate was aimed to re-house those displaced from old LNTK. The redevelopment summary and sitemap of new NTK Estate is presented in Table 3 and Figure 6 respectively.

Table 3. Development summary of NTK Estate

	UNTK	LNTK
Year of intake	2002, 2009	2012
Number of blocks	9	5
Number of residential flats*	6,700	4,200
Authorized population	16,300	10,000

Sources: Hong Kong Housing Authority (2014),
Hong Kong Housing Department (2007)
*As of March 2014

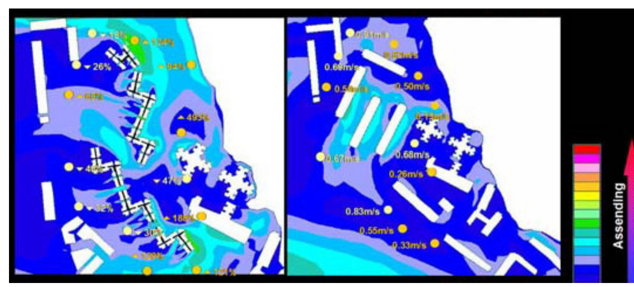


A: Lower Ngau Tau Kok Estate B: Upper Ngau Tau Kok Estate

Figure 6. Sitemap of Ngau Tau Kok Estate
Source: Hong Kong Housing Authority (2010)

The redevelopment of UNTK Estate and LNTK Estate was carried out under the concept of 'Building a Sustainable Community.' In order to ensure the environmental sustainability of the community, the HKHA applied microclimate studies in the planning and design of the redevelopment of NTK Estate.

In the process of the microclimate studies, a few on-site measurements were employed. The direction and velocity of prevailing wind affecting the site were measured by Wind tunnel test. Together with the computational fluid dynamics simulations, the test result provided foundational information determining the configuration of housing blocks to optimize the ventilation of the site. In UNTK Estate, for example, a wind corridor was considered in the master planning based on the wind tunnel testing result, and the configuration and orientation of housing blocks were adapted to improve the wind speed between 1.5 to 3m/s (Figure 7). The HKHA's internal survey revealed that 91% of the residents were very satisfied with the ventilation conditions of the site (HKHA, 2010).



<After redevelopment> <Before redevelopment>

Figure 7. Adjustment of housing block configuration after wind testing
Source: Hong Kong Housing Authority (2010)

In addition, the VDF of each flat was also measured to improve the view and daylight coming into the inside of housing units and common areas (Figure 8). The enhanced natural lighting and ventilation in the corridors have contributed to the energy saving up to 15% (HKHA, 2010).

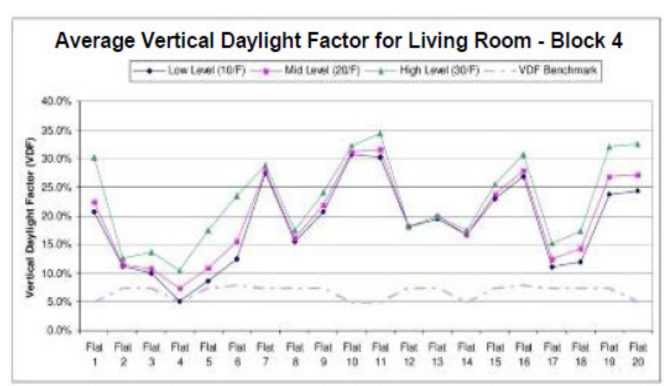


Figure 8. VDF measurement result for UNTK Estate
Source: Hong Kong Housing Authority (2010)

Due to the comprehensive approach to the building and site environmental quality, the redevelopment of UNTK Estate was certified 'Platinum' standard, the highest rating of the HK-BEAM, in 2005 with the significant credits on 'Site Aspects (82% of the total credits achieved)' and 'Indoor Environmental Quality (93% of the total credits achieved)' (Hong Kong Housing Authority, 2010) .

In the case of LNTK Estate redevelopment, since it was launched after 2006, this project was required to conduct the Air Ventilation Assessment. The AVA result, as shown Figure 9, proved that the air flow of the surrounding areas would be enhanced after the redevelopment.

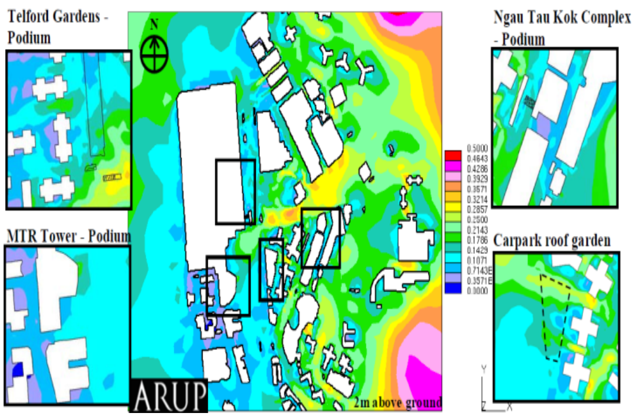


Figure 9. AVA result for the proposed LNTK Estate redevelopment plan
Source: Hong Kong Housing Authority (2008)

② North East New Territories (NENT) New Development Areas (NDA)

The New Development Areas (NDA) have been strategically designated to be developed for economic growth in Hong Kong. The North East New Territories are part of the NDA and will be comprised of three new towns in Kwu Tung North (KTN), Fanling North (FLN) and Ping Che/Ta Kwu Ling (PC/TKL). The study to investigate the present conditions of the sites and development potentials is currently carried out by the Planning Department. Upon completion, the areas will provide 60,700 new houses to accommodate 174,900 residents (Hong Kong Legislative Council, 2014). The development summary is presented in Table 4, and the location map of the development areas is illustrated in Figure 10.

Table 4. Development summary of KTN and FLN NDA

	KTN	FLN	Total
Area	450 ha	164ha	614 ha
New population	101,600	73,300	174,900
New residential units	35,400	25,300	60,700
Max. plot ratio	3.5-6	2-6	-
Max. building heights	20-35 storeys	12-35	-

Source: Hong Kong Legislative Council (2014)
Note: The detailed development plan for PC/TKL has not yet been drawn.

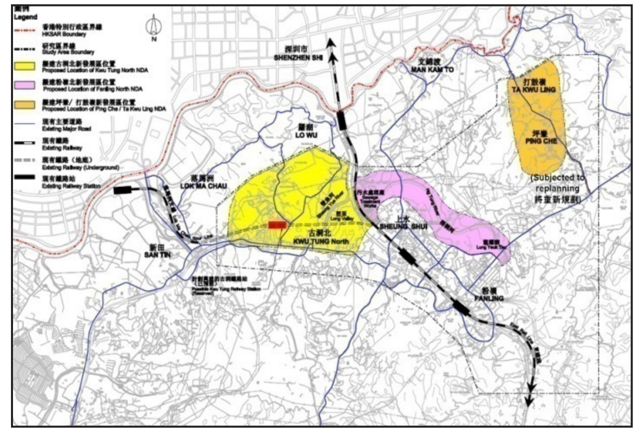


Figure 10. Development area location map
Source: Hong Kong Planning Department (2014)

Since the development of NDA is initiated and implemented by the government, AVA was undertaken to examine the wind availability and ventilation performance of the proposed plans for the sites and surrounding areas. The result of AVA identified that there was no major wind problems in the proposed plans (Hong Kong Civil Engineering and Development Department and Planning Department, 2007).

In the case of KTN NDA (Figure 11), for example, the AVA result verified that the east-west long strip type planning alignment and the configuration of wind corridors were conducive to good ventilation of the site. Several planning and design recommendations have also been provided. The buildings at the end of the east-west planning strip were configured in parallel with the direction of the prevailing wind to preserve the air flow into the inner sites, and terraced podium design was suggested for the town centre area.

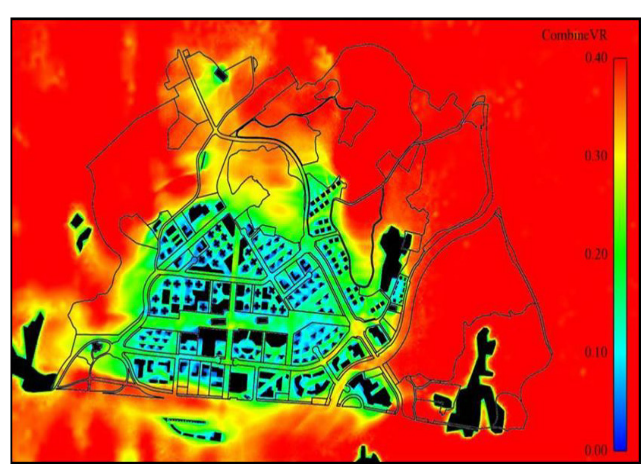


Figure 11. Annual Weighted Average Wind Velocity Ratio
Source: Hong Kong Civil Engineering and Development Department and Planning Department (2007)

4. IMPLICATIONS OF THE HONG KONG CASE FOR POLICY IMPLEMENTATION IN SOUTH KOREA

(1) Problems of daylight and natural ventilation of super high-rise housing in South Korea

With the rapid growth of major cities in South Korea, the pursuit of high-rise and high-density developments for the efficient use of land has been unavoidable. In particular, super high-rise apartments have been increasingly developed in metropolitan areas since the 1990s (Kim and Lee, 2005).

The development of super high-rise, high-density housing, however, has been criticized for paying little attention to residential comfort, which largely relies on indoor environmental quality (Baik and Kang, 2005; Kim and Lee, 2005). The advanced building technologies to increase air tightness for efficient energy use have given rise to the lack of natural cross ventilation inside housing units, increased the indoor air pollution and affected residents' health and comfort (Cho and Pang, 2012; Jang, 2010). In addition, the housing block design has often been criticized for hygiene problems caused by the lack of natural lighting and ventilation, especially of the lower floor units (Chang and Kim, 2012).

Indeed, some of the empirical studies have demonstrated that light and ventilation in super high-rise housing in South Korea have affected the residents' health significantly (See, for example, Baik and Kang, 2005; Kim, 2012; Sohn, 2012). In addition, the increased use of mechanical cooling and heating systems has been raised as an energy conservation and public health issue (Lee, 2012). Thus, there is a consensus that adequate standards of lighting and ventilation for super high-rise apartments should be a statutory requirement in the planning and design process to ensure a healthy housing environment.

In South Korea, the lighting and ventilation standards for residential buildings are currently regulated by state statutory building regulations in concert with the local authorities' building standards. However, these building requirements were enacted about twenty to fifty years ago and consequently are unable to properly support the present needs for a healthy environment for homes in the increasingly diversified types of housing.

(2) Building Regulations and Incentive Systems in South Korea

The present building requirements for daylight and natural ventilation for housing development in South Korea are shown in Table 5. It is notable that Hong Kong and South Korea have the following features in common.

- Mandatory standards on the micro scale regulated by Building Regulations
- Advisory requirements on the housing block scale promoted by incentive systems
- Progressive engagement of the private sector encouraged with incentive systems
- Use of building environmental assessment tools facilitated

Similar to the Hong Kong case, the South Korean government also provides GFA concessions and financial support to the developments that are awarded the 'Green Building Certificate' or satisfy the 'Building Design Standards for Energy Conservation.' The requirements for the development incentives usually involve the housing design for more favorable ventilation and green features.

However, there are a few aspects which are only shown in the South Korean case. First of all, with regard to daylight regulations, the building heights and the distances between buildings are of

Table 5. Building requirements for lighting and ventilation of residential buildings in South Korea

Category	Items	Scale
Mandatory	BAEO[1)] 86 (under BA[2)]) - Cap on building heights (Minimum distance from site boundary to the north:1.5m for building height of 9m or lower, half of building height for the part of building higher than 9m) -Minimum distance between buildings (daylight on winter solstice considered)	Housing block
	BR (fire protection) 17 Minimum size of windows (1/10 for lighting, 1/20 for ventilation)	Room
	BR (smoke exhaustion equipment) 14 Minimum size of smoke ventilation windows (various according to conditions of the 'external air' faced into by windows) and minimum level of ACH	Room, Flat
	Multifamily Housing Design Guidelines (under HA[3)]) - Assessment of design utilizing natural lighting and ventilation - Bedroom and dining room windows faced to external air - Advisory requirements included	Room, Flat, Housing block, Housing estate
Advisory	Building Design Standards for Energy Conservation Design improving natural lighting and ventilation encouraged	
	CHHC Scheme (under HA) - Controls on harmful building materials and installation of ventilation equipment - Advisory requirements included	Room, Flat
	GBCS Partly assessing lighting and ventilation environment	Room, Flat, Housing block, Housing estate, Neighborhood

Sources: Extracted from Korean Ministry of Land, Infrastructure and Transport (2013a, 2013b) and Korean Ministry of Land, Transport and Maritime Affairs (2010).
Notes: [1)] BAEO: Building Act Enforcement Ordinance, [2)] BA: Building Act [3)] HA: Housing Act

importance in South Korea (Figure 12), rather than the VDF from the external walls of surrounding buildings. In South Korea, having enough sunlight in a house is important due to the cold weather in winter. In addition, it is more feasible to assign distances between buildings due to the lower density relative to Hong Kong. It reflects the different climatic conditions and built environment in the two regions.

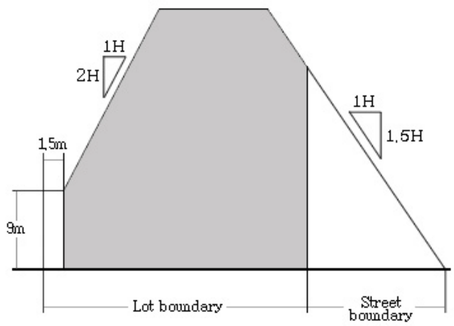


Figure 12. Measurement of the building height for lighting
Source: Korean Ministry of Land, Infrastructure and Transport(2013b)

Another remarkable feature is that concerning the indoor air quality, the indoor sources of air pollution causing Sick Building Syndrome or mold have been at the center of the issue. In effect, a survey result showed that 93.5% of the respondents considered the indoor air quality as an important factor of their home purchase decision (Korean Ministry of Environment, 2007). For example, the recently promulgated CHHC Scheme deals exclusively with the controls of the harmful building materials (e.g. VOCs, HCHD) and encourages the use of environment-friendly materials in housing construction.

The similarities and differences of the building regulations for natural lighting and ventilation in Hong Kong and South Korea are summarized in Table 6.

Table 6. The similarities and differences of natural lighting and ventilation regulations of Hong Kong and South Korea

		Hong Kong	South Korea
Similarities		• Mandatory standards on the micro scale regulated by Building Regulations • Advisory requirements on the housing block scale promoted by incentive systems • Progressive engagement of the private sector encouraged with incentive systems • Use of building environmental assessment tools facilitated	
Differences	Concern of lighting regulations	Vertical Daylight Factor	Building heights and distances between buildings
	Concern of indoor air quality	Housing estate or neighborhood scale factors also considered	Indoor sources of air pollution focused
	Planning and design guidelines	Detailed guidelines for specific elements available	General recommendations (relatively less detailed)

(3) Policy implications

The differences between Hong Kong and South Korea with regard to the lighting and ventilation requirements are the corollaries of the different contexts of the two regions. However, the distinctiveness of one case could provide new insights to the other case. Therefore, this section discusses the implications of Hong Kong's practices for healthy housing policies in South Korea, particularly in pursuit of better natural lighting and ventilation for super high-rise housing developments.

To begin with, it is suggested that the South Korean government broaden the scope in which performance-based standards are applied. In South Korea, except for the minimum amount of air change per hour stipulated by the building regulation regarding smoke exhaustion equipment (Table 5), most of the building requirements are found to be either prescriptive or strategic in nature. Although the requirements are straightforward with the predetermined figures, they are likely to be rigidly applied in the plans regardless of the locations, the form and arrangement of housing blocks and the positions of windows. Although not all the requirements can be assessed by performance-based standards, these help reflect the actual conditions of the site environment more accurately.

One example can be applied to the building design with regard to natural lighting. The actual amount of daylight received in the housing units in different locations on different floors should be measured by using more practical simulation models, like the UVA method in Hong Kong, to improve the conditions of the poorly lit areas of high-rise housing blocks, such as the lower floor units and re-entrant areas. Considering the current trend of high-rise and high-density development in South Korea, the adjusted UVA method according to the South Korean context can be applied in order to consider not only the vertical angle between the building height and the adjacent street width (or distance between two buildings), but also the horizontal open area where there is also reflected light. Accordingly, the window design of high-rise housing blocks should be more diversified depending on the floors where the windows are located.

In addition, considering that the natural ventilation performance depends on the primary air flows in the site, the locations and types of windows and the openable area of the window (Cho and Pang, 2012), the existing 'minimum size of windows' regulation should become more specific with the openable area of window standards, together with adequate cross ventilation planning. Furthermore, the current high-rise housing estate design, especially the arrangement of tower type housing blocks, tends to hinge on the favorable views from the inside of the units and the landscape of the whole site. Thus, it seems necessary to mandate that developers submit an air-flow simulation report, like the AVA in Hong Kong, to take into account the actual impact of the housing block design on the natural ventilation of the site.

Another issue to be noted is that the South Korean government should take a more comprehensive approach to the lighting and ventilation regulations with particular regard to the scales of implementation. A healthy environment in high-density housing development involves various aspects of the built environment and human conditions. Therefore, the policy measures also need to embrace the multidisciplinary features of the concept.

Table 7. Policy implications for high-rise, high-density housing development in South Korea

Policy implications	Purpose	Examples
• Development of performance-based standards rather than prescriptive requirements	To reflect the actual conditions of the site environment more accurately	• Using minimum VDF and ACH standards instead of predetermined window size regulation • Applying adjusted UVA methods for better natural lighting of poorly lit areas • Using 'openable area of window' standards • Mandating air-flow impact assessment to ensure better natural ventilation
• Expansion of the scales of the factors affecting natural lighting and ventilation	To embrace various aspects of the built environment and human conditions affecting healthy housing environments	Taking not only housing unit scale aspects, but also housing block, housing estate and neighborhood scale conditions into consideration in planning
• Development of more practical, detailed design guidelines	To help effective application of the lighting and ventilation regulations	Providing specific recommendations with a wide range of design options for window design, depth and shape of rooms, design of lower floor units, housing block design and arrangement of housing blocks

The South Korean policies tend to focus extensively on the controls of the indoor conditions of housing units. For example, while the building regulations for lighting and ventilation are concerned with the housing unit scale, the CHHC Scheme and GBC System also deal mainly with the use of environment-friendly building materials and the installation of ventilation equipment inside the units. They pay little attention to the external factors of housing units, such as housing block design and the spatial relationship with surrounding buildings. Although the Multifamily Housing Design Guidelines Scheme assesses the design strategies of housing development in terms of the lighting and ventilation performance at the housing estate scale, the standards are so abstract and ambiguous that the efficacy of the application is questionable. Therefore, it is recommended that the future Korean policy measures with regard to lighting and ventilation in pursuit of a healthy housing environment address not only the housing unit, but also the housing block, housing estate and neighborhood scale conditions.

Last but not least, it is also suggested that the lighting and ventilation requirements in South Korea incorporate more practical design guidelines. Except for the Multifamily Housing Design Guidelines Scheme, most of the existing regulations and requirements are intended to measure the building performance numerically. The specific planning and design guidelines on how to create a healthy environment in high-density housing are almost non-existent in the statutory framework.

Although it is agreed that too many detailed guidelines may possibly lead to uniform housing design, specific recommendations with a wide range of design options would enhance the efficacy of the application of the building regulations and requirements in order to safeguard the adequate lighting and ventilation quality in residential buildings. Specifically, this method can be applied to window design, depth and shape of rooms, design of lower floor units, housing block design and arrangement of housing blocks. For doing so, a substantial amount of empirical studies should be conducted with regard to the applicable design methods by government bodies (e.g. Ministry of Land, Infrastructure and Transport, Ministry of Environment, etc.) in collaboration with non-government organizations (e.g. Korea Institute of Construction Technology, Planners Association, Institute of Architects, etc.) and the private sector (e.g. housing development companies).

The policy implications of the Hong Kong case for policy implementation in South Korea are summarized in Table 7.

5. CONCLUSIONS

Comfortable indoor air and natural lighting conditions are important elements that comprise a healthy housing environment. Therefore, government regulations for the lighting and ventilation standards play a crucial role in ensuring an adequate level of daylight and fresh air in housing units.

In this view, this study has examined the features of the building requirements for natural lighting and ventilation of residential buildings in Hong Kong. The findings revealed that the Hong Kong government has strived to regulate the lighting and ventilation standards of residential buildings by various building regulations and guidelines. The strict application of building regulations on a micro scale and the implementation of flexible incentive systems on a macro scale were found. The efforts to call for more active participation of developers and to make the most use of the building environmental assessment tools were also noted.

However, the Hong Kong case is to some extent distinguished from the South Korean one, in that it adopts more performance-based standards, considers the external factors of the lighting and ventilation conditions as well as the indoor elements and provides very specific planning and design guidelines. Especially, the application of performance-based standards and neighborhood-scale ventilation assessment to government (re)development plans was illustrated as brief case studies.

Despite the different climatic conditions and socio-political contexts of the two regions, these findings yield several implications for future policy implementation in South Korea. The findings suggest that the South Korean government apply on-site measurement methods to reflect the actual site environmental conditions more accurately and that it broaden the scope and scale of the lighting and ventilation regulations with more specific, practical planning and design guidelines, particularly regarding the design of the windows, housing block and housing estate. A possible direction of future studies would be investigating the practical ways to apply these implications to the relevant areas of the environmental policy in the South Korean context.

High-rise and high-density are likely to continue to be a major housing development pattern in the future in South Korea. A more careful, comprehensive approach to the lighting and ventilation regulations, based on the recommendations of this study, would contribute to creating a healthy environment in super high-rise residential buildings.

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