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Quality Public Housing in a Vertical City
摩天城市中的优质公营房屋

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Abstract | 摘要

The Hong Kong Housing Authority (HKHA) provides affordable public rental housing to meet the needs of about 30% of the seven million inhabitants of Hong Kong. As a result, HKHA has a major role to play in shaping the city fabric. We are committed to building sustainable communities to promote green, safe, and healthy living, achieving better public housing design as we truly believe in living in harmony based on a people-centric approach. Given tight financial and land resources we need to tackle the multi-faceted challenges of housing design in the high-rise high density compact city. When we face problems, we have to explore options, conduct Research & Development, and find innovative solutions. These are our drivers for continuous improvement. As a result, we find success stories in improving the process as well as the products of our quality public housing in a vertical city.

Keywords: High Density Compact City, Innovative Initiatives, People-Centric Design, Quality Public Housing, Sustainable Community, Vertical City

香港房屋委员会（房委会）提供满足香港700万人口的住屋需求中近三成的可担付公营房屋。因此，房委会在塑造城市肌理中担任重要的角色。我们致力建设可持续社区，促进绿色环保、安全、健康的生活，成就更优质的公营房屋设计，因为我们相信以人为本的策略是构建和谐生活的根基。由于资金和土地资源紧绌，在高密度的紧凑摩天城市建设优质房屋，我们需要应对多方面的挑战。处理问题时，我们必须积极探讨各种方案，进行研究和开发，并寻找创新的解决方法。这些都是我们持续改进的推动力。因此，我们不仅成功改善了建设的过程，也缔造出垂直城市当中优质的公营房屋。

关键词：高密度城市、创新措施、以人为本的设计、优质公营房屋、可持续社区、垂直城市

1. Introduction

1.1
Established in 1973 under the Housing Ordinance, the Hong Kong Housing Authority (HKHA) develops and implements one of the largest public housing programs in the World. Today, about 30% of Hong Kong's seven million inhabitants live in about 750,000 flats in public rental estates. Another 15% of our population is living in subsidized sale flats. In support of the government policy on housing, HKHA plans, builds, manages and maintains different types of subsidized public housing to meet the housing needs of those who cannot afford private housing in Hong Kong. According to the latest update to the Long Term Housing Strategy as contained in the Policy Address 2016,[1] the government has further adjusted the projection of housing demand for the 10-year period from 2016/17 to 2025/26, and the public housing supply target will comprise 200,000 public rental housing units and 80,000 subsidized sale flats. With such a sizable program to implement whilst ensuring quality, safe and healthy living in such a high density compact city, as well as for people of all ages and abilities, it is quite a challenging task to accomplish.

1. 引言

1.1
香港房屋委员会（下称「房委会」）于1973年根据《房屋条例》成立，负责发展和推行全球其中之一最大型的公营房屋计划。目前，本港有700万人，其中约三成(约750 000个单位)居住在公共租住屋村（下称「公屋」），另有15%居住在资助出售房屋单位。配合政府的房屋政策，房委会规划、兴建、管理和维修不同类型的资助房屋，为无法负担私人房屋的人士解决住屋需要。根据《二零一六年施政报告》[1] 所载的最新长远房屋策略，政府已进一步调整2016/17至2025/26年度10年期内的房屋需求预测，而公营房屋供应目标将包括200 000个公屋单位和80 000 个资助出售房屋单位。要推展规模如此庞大的公营房屋计划，并同时确保不同年龄和能力的人士均能在这个人口密集的城市中享受优质、安全和健康的生活，实在是一项艰巨的挑战。

1.2
房委会秉持「关怀为本、顾客为本、创新为本、尽心为本」的基本信念不断创新，致力提升房屋质素，令屋宇设计更以人为本。房委会一直以关爱的态度，努力推动

1.2

Upholding the 4C core values – Caring, Customer-focused, Creative and Committed – HKHA is constantly exploring innovative ways to triumph a higher standard of quality housing and people-oriented design. To embrace a caring attitude to foster social, economic and environmental sustainability, HKHA adopts passive design and other environmental initiatives and conducts state-of-the-art micro-climate studies to create quality homes for residents in a green and healthy living environment. HKHA establishes the Modular Flat Design and applies mass customization to strike a better balance amongst various factors including valuable land resources, buildability, cost effectiveness, user-friendliness, safety, and healthy living for people. HKHA has also taken a proactive role in applying Building Information Modeling (BIM) and other IT applications to enhance safety, quality and durability, production efficiency, cost effectiveness and sustainability in design and construction. This paper gives an in-depth account of HKHA's experience on the application of innovative initiatives for our quality public housing in a vertical city.

2. Passive Design

Accessibility to sufficient natural ventilation and daylight without resorting to artificial means is of paramount importance in composing a healthy living environment for our tenants. Since 2004, HKHA has been applying passive design in all new public housing projects during the early planning and design stages, to create quality living environment and improve the environmental performance of the projects. With the use of state-of-the-art computerized simulation models, we optimize the local climate for tenants' comfort inside the domestic flats and provide cross ventilated corridors inside domestic buildings to create an "urban oasis" in estate planning. We conduct environmental assessments at early planning stages to identify areas with stagnant air, noise, water pollution and other hazards to development. On-site measurement at post occupation stage validates the simulation study results at the design stage. Over the years, tenants' positive feedback through post occupation surveys also affirms the enhanced environmental performance.

Figure 1. Green Roof (Source: Housing Authority)
图1. 天台绿化（来源：香港房屋委员会）

2.1 Microclimate Studies

In refining the estate layout and building design for green and healthy living, we adopt a passive building design approach, through air ventilation assessment and micro-climate studies, to optimize the planning and design of buildings and open spaces. This provides healthy, quality living environment for tenants through optimal use of the natural resources such as wind environment, natural ventilation, daylight and solar radiation as well as energy consumption.

We configure and orient the domestic blocks to capture the prevailing wind, maximizing natural ventilation with the floor layout designed to enhance air ventilation with ample natural light penetrating into the buildings, including both semi-private areas at lift lobbies and corridors, and the private domain in each domestic flat.

2.2 Solar Heat Gain

Hong Kong lies in the tropical climate zone. Our design aims to minimize solar heat gain in domestic units in order to have higher energy efficiency and better human comfort. We apply the results of the micro-climate studies to design solar shading devices for reducing solar heat gain both on the building façade and in individual dwellings, to reduce the energy consumption by air conditioning and/or other mechanical ventilation means.

2.3 Heat Island Effect

Greening purifies air and mitigates the urban heat island effect apart from ecological and amenity values. Since 2010, the HKHA has adopted a green ratio of not less than 30% for public housing developments with a site area over 2 hectares, or 20% for smaller sites. To optimize utilization of land resources, other than provision of traditional at-grade planting at open space of the estates, we apply a slope greening and sky-rise greening method such as vertical and rooftop greening so as to meet the greening ratio target (a prerequisite to maximizing the housing production) and create a sustainable living environment subject to individual design and related environmental factors (Figure 1).

香港社会、经济和环境的可持续发展，并透过顺应自然的设计模式、其它环保措施及进行最先进的微气候研究，以期建造优质居所，让居民在环保和健康的环境中安居乐业。房委会又研发构件式单元设计和采用预制组件，在珍贵的土地资源、可建造性、成本效益、迎合使用者需要和为居民提供安全和健康生活等各方面取得理想的平衡。此外，房委会亦积极应用建筑信息模拟系统和其他资讯科技，以改善设计和施工上的安全、品质、耐用程度、生产效率、成本效益和可持续性。本文将深入分享房委会的经验，阐述我们如何利用创新科技和措施在香港这个摩天城市中提供优质公营房屋。

2. 顺应自然的设计

无须借助人工方式而能够提供充足的自然通风和采光，对营造健康的居住环境极为重要。房委会自2004年起，已在所有新建公营房屋项目的早期规划和设计阶段采用顺应自然的设计，以缔造优质的居住环境，提升房屋项目的环保成效。我们利用先进的电脑模拟技术模拟不同情境，来优化地区性的气候特征，使居民在住宅单位内感觉更为舒适，并在住宅大厦内各分层走廊加入对流通风设计，以期在屋村规划中构建「都市绿洲」。我们亦在早期规划阶段进行环境评估，鉴定风势微弱的区域，以及识别对发展项目造成噪音、水污染和其他危害的范围。在发展项目入伙后，我们会进行现场测量，核证设计阶段的模拟研究结果是否准确。多年来，居民在新落成屋村的住户意见调查中都给予正面评价，足证公营房屋的环保成效不断进 步。

2.1 微气候研究

为了优化屋村布局和实现环保、健康的居住环境，我们在改良屋村布局和建筑设计时采用顺应自然的建筑设计模式，并进行空气流通评估和微气候研究，以优化大厦和休憩空间的规划和设计。这种设计模式，透过善用风环境、自然通风、日照和热辐射等天然资源，既可节约能源，又为住户提供健康、优质的居住环境。

大厦布局和坐向均会配合该处的主导风，让分层布局设计有利空气流通和让天然日光透进大厦内部，当中包括属于半私人范围的升降机大堂和走廊，以及每个单位的私人空间。

2.2 太阳热能吸收

由于香港位处热带气候地区，因此我们的建筑设计，会以尽量减少单位所吸收的太阳热能为目标，并同时提升能源效益和优化住户的舒适度。我们根据微气候研究结果设计遮阳装置，以减低大厦外墙和个别单位吸收的太阳热能，从而减少空调系统及 / 或机械通风系统的能源消耗。

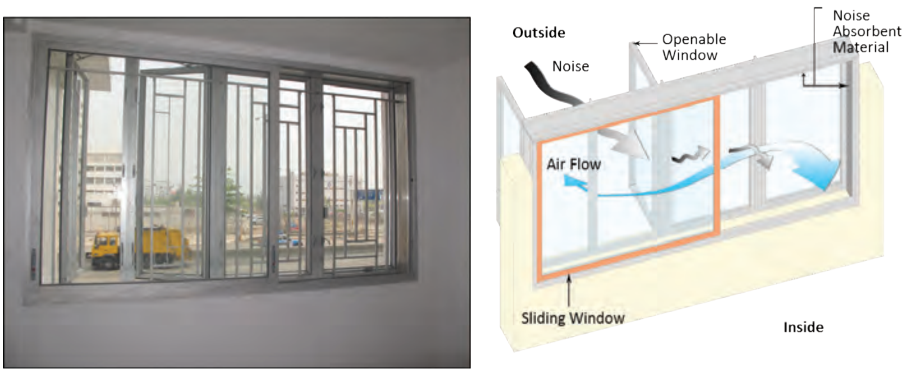

Figure 2. Acoustic window adopted in San Po Kong Public Rental Housing, reduced noise attenuation by up to 8 db(A) (Source: Housing Authority)
图2. 新蒲岗公营房屋发展项目采用的减音窗设计，减音效果达8分贝左右（来源：香港房屋委员会）

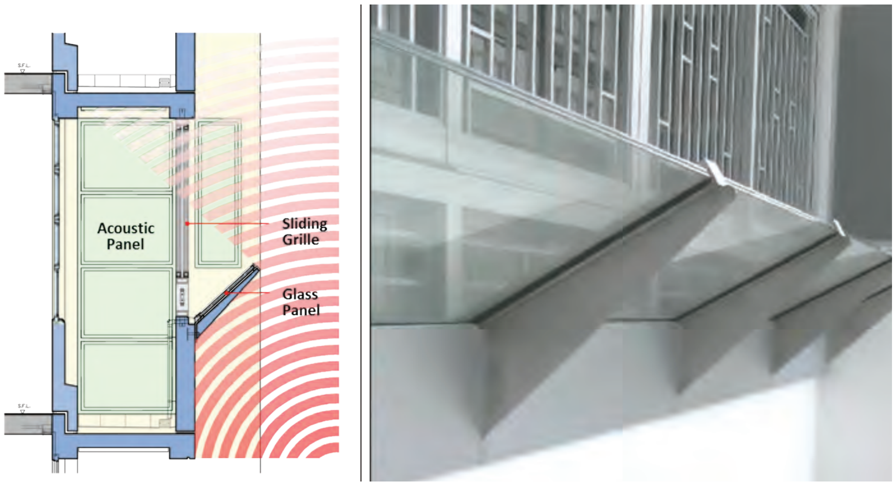

Figure 3. Acoustic balcony design adopted in Sai Chuen Road Public Housing Development (Source: Housing Authority)
图3. 西村路公营房屋发展项目采用减音露台设计（来源：香港房屋委员会）

2.4 Integrated application of BIM and GIS in Environmental Studies

Together with an integrated application of BIM (Building Information Modeling) and GIS (Geographic Information System), we can apply environmental studies – including lighting, ventilation, energy, carbon emission, green design etc. – and prepare quick design visualizations for visual impact assessments during the feasibility and planning stage, thereby enabling our public housing more user-friendliness. For a detailed application of BIM and GIS, refer to Section 5 of this paper.

3. Noise Mitigation

Hong Kong is renowned for its high density living environment. With limited land sources, residential developments, including public housing developments, may usually be located in close proximity to heavily trafficked roads or other noise sources. Embracing a caring attitude to create a healthy living environment to our residents in public housing estates, HKHA has applied a host of noise mitigation measures to reduce the impact and nuisance. Depending on the individual characteristics of the site, we apply noise mitigation measures at the source, at the propagation path, and/or at receiving end. At-source mitigation measures include application of low noise road surfacing and construction of noise enclosures. Mitigation measures at the path of propagation including building setbacks and orientation, erection of noise barriers, and non-noise sensitive building design. Vertical fins are commonly adopted as the mitigation measures at the receiver end.

To tackle the most severe noise challenges without compromising the performance of natural ventilation for the flats, HKHA has come up with the innovative acoustic windows and acoustic balcony design for shielding noise impact. These innovative designs could secure a comfortable environment whilst maintaining the valuable natural ventilation at the living areas (Figures 2 and 3).

An acoustic window design was adopted in San Po Kong Public Housing Development (Figure 2). Upon testing for different scenarios, it was established that the acoustic window with noise absorption materials at the window frame could achieve noise attenuation up to about 8 dB(A).

An acoustic balcony design was adopted in Sai Chuen Road Public Housing Development

2.3 热岛效应

绿化除可改善生态环境和舒适价值外，还可净化空气和缓减市区热岛效应的影响。房委会于2010年订立标准，凡地盘面积超过两公顷的公营房屋发展项目，绿化比率不得少于地盘总面积的30%;较小的地盘则不少于20%。为善用土地资源和缔造可持续的居住环境，我们除采用传统的地面种植外，还会视乎个别项目的设计和其他相关的环境因素，使用斜坡绿化和高空绿化（例如垂直绿化和天台绿化）方法，以期达到目标绿化比率。这也是尽量提高建屋量的其中一项前提（图1）。

2.4 建筑信息模拟系统(BIM)和地理资讯系统(GIS)的综合应用

在可行性研究和规划阶段，我们综合应用建筑信息模拟系统及地理资讯系统技术，以便对照明、通风、能源、碳排放、环保设计等环境项目进行研究。这些科技迅速地将设计呈现眼前，有助我们进行视觉评估影响，令公营房屋更切合使用者的需要。有关建筑信息模拟系统和地理资讯系统的应用详情，请参阅下文第五节。

3. 缓减噪音措施

香港居住密度之高，举世闻名。由于土地资源有限，不少住宅发展项目（包括公营房屋发展项目）或会贴近交通繁忙的道路或其他噪音源头。房委会以关怀为本，采取多项缓减措施，以期减低噪音对住户的影响和滋扰，致力为公营房屋居民缔造健康的居住环境。我们会视乎各地盘特性，针对噪音源头、传播路径和 / 或在受影响单位，采取缓减措施。在噪音源头方面，我们实施的缓减措施包括使用减低噪音的路面物料铺设道路和设置隔音罩。在传播路径方面，则包括楼宇后移、改变楼宇坐向、竖设隔音屏障，以及采用隔音的楼宇布局设计。我们亦会为受影响单位安装垂直翼墙，以减低噪音影响。

面对严峻的噪音问题，房委会研发创新的减音窗和减音露台设计，务求在不影响单位天然通风的情况下阻隔噪音。这些设计既能提供舒适的居住环境，又能保持难得的天然通风（图2、3）。

我们在新蒲岗的公营房屋发展项目采用减音窗设计（图2）。我们曾测试不同的设计方案，结果发现配备吸音物料窗框的减音窗，其减音效果高达8分贝左右。

我们又在西村路荣昌村公营房屋发展项目采用减音露台设计（图3）。结果发现在单位露台加装吸音物料后，受影响单位的噪音可减低6.4分贝。我们设计的减音露台再加上其他缓减措施，符合规定噪音比率的单位大幅提升至90%，而最高噪音声级则减至75分贝。

(Figure 3). Together with the application of noise absorption linings at the balcony, the balcony could achieve noise reduction up to 6.4 dB(A) for the proposed development at Wing Cheong Chuen at Sai Chuen Road. With the provision of the balcony structure and other mitigation measures, the noise compliance rate was significantly improved to 90%, and the maximum noise level was reduced to 75 dB(A).

Acoustic balcony design has been further enhanced, which amalgamates the acoustic window concept in the first generation of acoustic balconies. To ameliorate the incidence of noise through the balcony door into the flat, a sliding screen is installed in front of the balcony door on the balcony. This arrangement allows the ventilation path to be of decent width. Upon testing for different flats and enhanced balcony scenarios, it was established that, the enhanced acoustic balcony, with the fittings as stated above, could achieve relative noise attenuation up to around 10 dB(A), which was even higher than acoustic window and the first generation of acoustic balconies. It would be an effective design for noise mitigation whilst at the same time allowing desirable natural air ventilation for the habitable area of the flat.

4. Carbon Emission Estimation (CEE)

The construction and maintenance of a building is one of the major sources of carbon emissions that lead to global warming. To provide a green and sustainable building design, we found the need to devise a straight and practical indicator to quantify the comprehensive impacts of residential buildings on the environment.

Since 2011, HKHA has further developed a user-friendly CEE methodology to holistically evaluate the carbon emissions of new public housing developments throughout the building life cycle, to ensure the housing design is optimized by comparing against the benchmarking estates.

In estimating CO2 emission of buildings, it is required to define the system boundary first since it affects the estimation significantly. Among the system boundaries commonly used as shown in Figure 4, we choose to adopt the "Cradle to Grave" approach instead of "Cradle to Cradle" approach in our methodology after balancing the completeness of the methodology and practical difficulties in gathering CO2 emission figures in the recycling phase (Figure 4).

Humphrey et al. in their study[2] stated that the environmental impact of high-rise residential blocks was dominated by concrete, steel reinforcement and timber formwork primarily because the structural frame of the building is reinforced concrete. To make our methodology practical and convenient for the use of building designers, we focus on the CO_2 emission associated with these major construction materials and building operations from cradle to grave for a building life of 100 years. The embodied carbon in architectural and BS materials and their replacement in the course of building life is excluded from the carbon emission estimation. Six aspects, namely (I) Materials Consumed during Construction, (II) Materials for Structure, (III) Communal Building Services (BS) Installations, (IV) Renewable Energy Installations, (V) Tree and (VI) Demolition, have been identified in the methodology (Figure 5). Tenants' energy consumption, which is beyond HKHA's control, is outside the boundary of our model. After calculating the amount of carbon emission, we compare the figures against the Benchmark Block (New Harmony One Block) and Benchmark Estate (Kai Tak Site 1A), on per GFA, per CFA, and per Flat basis. All aspects are compared. When

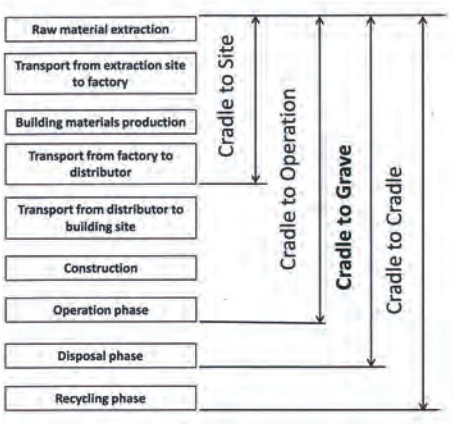

Figure 4. System boundaries in previous studies (Source: Housing Authority)
图4. 前研究的估算系统范围（来源：香港房屋委员会）

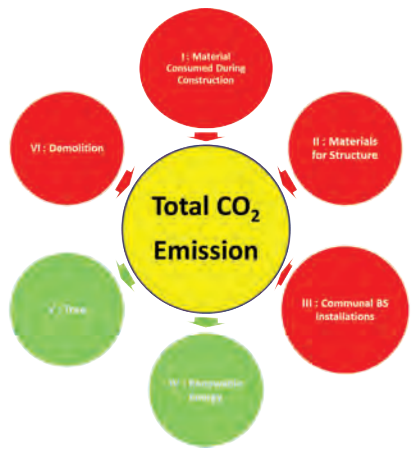

Figure 5. Methodology for Carbon Emission Estimation (Source: Housing Authority)
图5. 碳排放量估算方法（来源：香港房屋委员会）

我们采纳第一代减音露台的减音窗概念，进一步改良减音露台的设计。为减低噪音经露台门进入单位，我们在露台门前加装拉趟屏板，这个安排使通风路径保持适当的阔度。根据为不同单位和各优化减音露台方案进行测试的结果，我们发现配备上述装置的优化减音露台，相对减音效果约达10分贝，比减音窗和第一代减音露台更胜一筹。因此，优化减音露台设计能同时有效缓减噪音和为单位的居住空间提供理想的天然通风。

4. 碳排放量估算

碳排放导致全球暖化，而建造楼宇和维修保养是碳排放的一大源头。为设计和建造环保和可持续的楼宇，我们认为有需要订立简单实用的指标，以量化楼宇对环境的整体影响。

房委会在2011年进一步制订简单易用的碳排放估算方法，全面地评估新建公营房屋发展项目整个生命周期的碳排放量，并借着与基准屋村设计作比较，确保房屋设计达到最佳效能。

由于估算系统涵盖的范围会大大影响估算结果，因此在估算楼宇的二氧化碳排放量前，我们必须先界定估算系统的范围。图4列出一些常用的估算系统范围，我们在衡量估算方法的完整性，以及在循环再造阶段收集二氧化碳排放量数据的实际困难后，选择了「从建造到拆卸」的方案，而非「从建造到建造」的方案（图4）。

正如Humphrey et al.的研究所述[2]，由于楼宇的结构框架主要以钢筋混凝土建造，故高层住宅大厦对环境的影响主要来自混凝土、钢筋和木模板。为方便楼宇设计者，我们提出的估算方法必须配合实际和易于使用。因此，我们的估算方法集中于楼宇从建造到拆卸期间，以上主要建材和楼宇营运所涉及的二氧化碳排放量，而楼宇的寿命设定为100年 。然而，建筑和屋宇装备物料的含碳量及在楼宇生命周期内更换物料的含碳量，则不会计算在碳排放量估算内。碳排放量估算方法涵盖以下六个范畴：(I) 施工期间所消耗的材料；(II) 楼宇结构材料；(III) 公用屋宇装备设施；(IV) 可再生能源系统；(V) 树木；以及(VI) 拆卸工程（图5）。此外，租户的能源耗用量非房委会所能控制，故不会纳入估算范围内。进行排碳量估算时，我们会以每个住宅单位的每平方米总楼面面积和每平方米建筑楼面面积的排碳量为基础，并按以上全部六个范畴与基准大厦(新和谐式一型)和基准屋村(启德1A地盘)作比较。如排放量超出基准，工程项目小组便须检讨设计和设法减少碳排放。

正如图5所显示，我们特意把两个「绿色」范畴，即范畴IV和V纳入估算方法之

benchmark figures are exceeded, the project team will be required to review the design and find rooms to reduce the carbon emission.

As shown in Figure 5, two "Green" aspects, i.e. Aspect IV and Aspect V are purposely included in our methodology. This arrangement is to facilitate our stocktaking for sustainable provisions with contributions in carbon-reduction and carbon-absorption.

From Figure 6, we can see that Aspects II and III are critically dominant (Figure 6). In particular for Aspect III (communal building services installations), it contributes to 60% of total carbon emissions. So, focusing on communal building services installations, we have developed our Energy Management System to systemize the implementation of our energy saving initiatives. In 2014, we have successfully lowered the Energy Performance Indicator (EnPI) from the original 30kWh/m^2 to 27kWh/m^2. In 2016, through the use of LED bulkheads in place of compact fluorescent lamp (CFL) luminaires as standard luminaires, we could further save 10% of communal energy, and have accordingly set the EnPI to 24kWh/m^2.

5. Building Information Modeling (BIM) and Information Technology (IT)

Building sustainably has always been one of our main objectives, and to this end, we continue to drive for innovation to improve the efficiency and environmental performance of our development. In the past ten years, we have devoted ourselves to integrate the use of new and innovative IT platforms, including BIM, Geographic Information System (GIS), and most recently, Radio-frequency identification (RFID) to enhance our design efficiency, improve on environmental performances of our buildings, and advance the quality and safety of our work for the entire building development life cycle.

5.1 Feasibility Study and Planning Stage

Since 2014, we have accomplished a small breakthrough by integrating the use of BIM and GIS for site planning and feasibility studies. By combining the 3D terrain and buildings of Hong Kong with BIM models of our estates, we were able to perform a number of studies in the 3D GIS environment, including visual impact assessments abd ridge line, vantage point, and shadow analyses. This is an important step towards minimizing the visual impact of our developments on the environment (Figure 7).

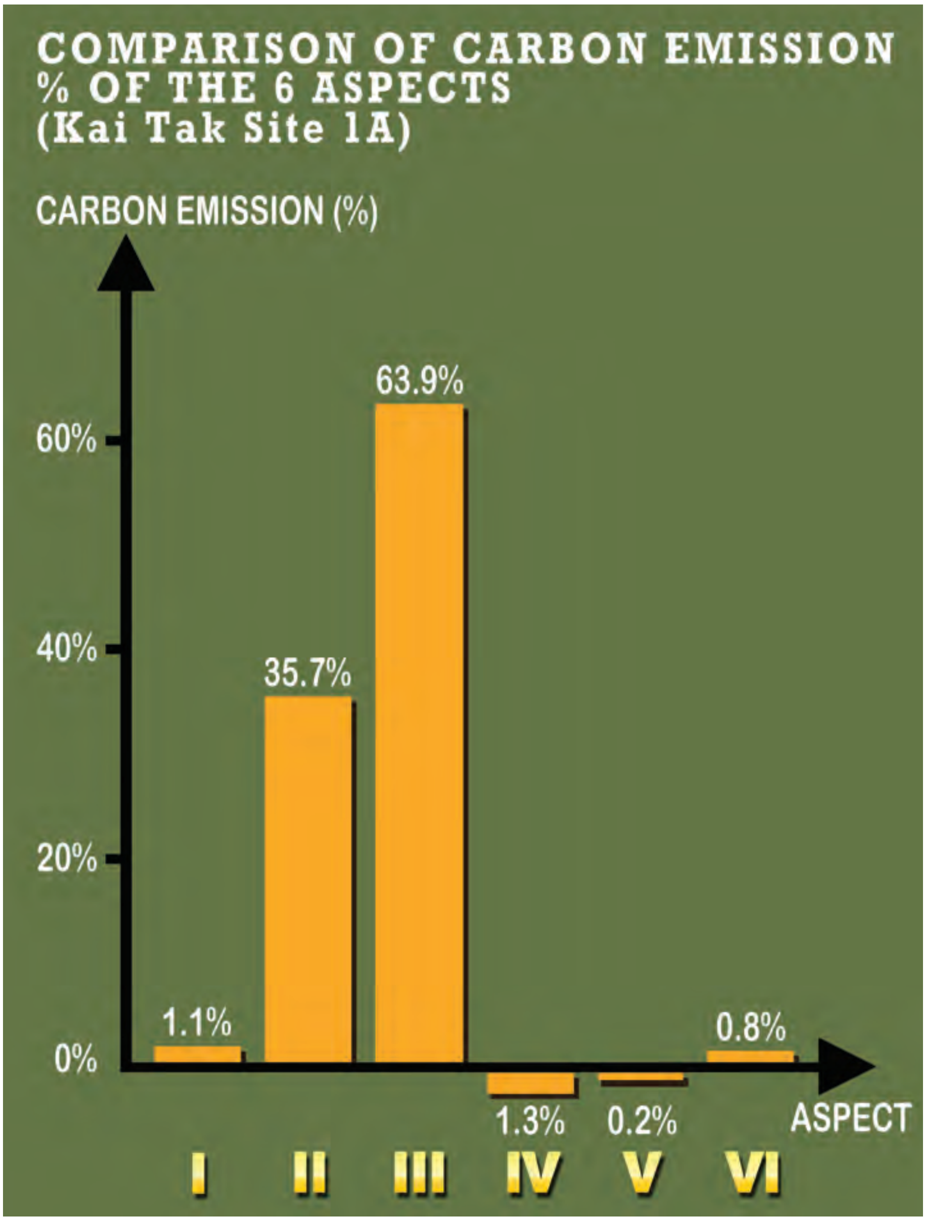

Figure 6. Comparison of Carbon Emission; percent of the 6 aspects (Source: Housing Authority)
图6. 碳排放量六个范畴的比较百分比（来源：香港房屋委员会）

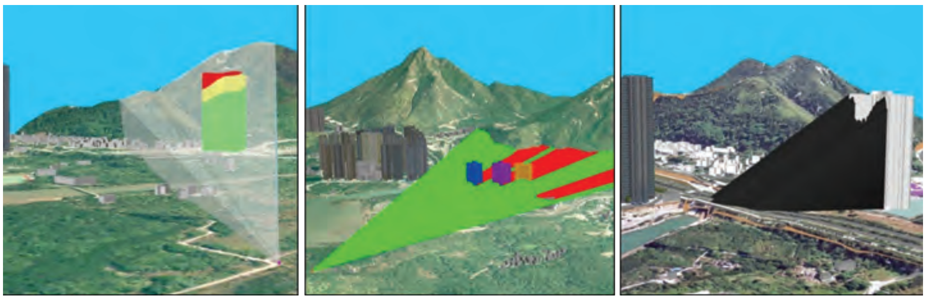

Figure 7. Ridge line analysis (Left) Vantage point analysis (Middle) Shadow Analysis (Right) (Source: Housing Authority)
图7. 山脊线评估（左）、了望点评估(中) 和 遮蔽分析(右)（来源：香港房屋委员会)

内，以方便我们估量有哪些可持续措施能有助减碳和吸碳。

从图6所见，范畴II和III为关键项目，特别是范畴III（公用屋宇装备设施），占总碳排放量60%。因此，我们针对公用屋宇装备设施制订能源管理体系，以便有系统地推行节能措施 （图6）。 2014年，我们成功将能源表现指标由最初的每平方米30千瓦小时，降至每平方米27千瓦小时。2016年，我们会使用发光二极管(LED)顶灯代替小型萤光灯管作为公众地方的基本照明，以期进一步节省10% 公用装置的耗电量，而能源表现指标亦会相应下调至每平方米24千瓦小时。

5. 建筑信息模拟系统和资讯科技

实现可持续建筑是我们一直追求的其中一项主要目标。为此，我们不断研发创新技术，以优化我们的发展项目在效能和环保

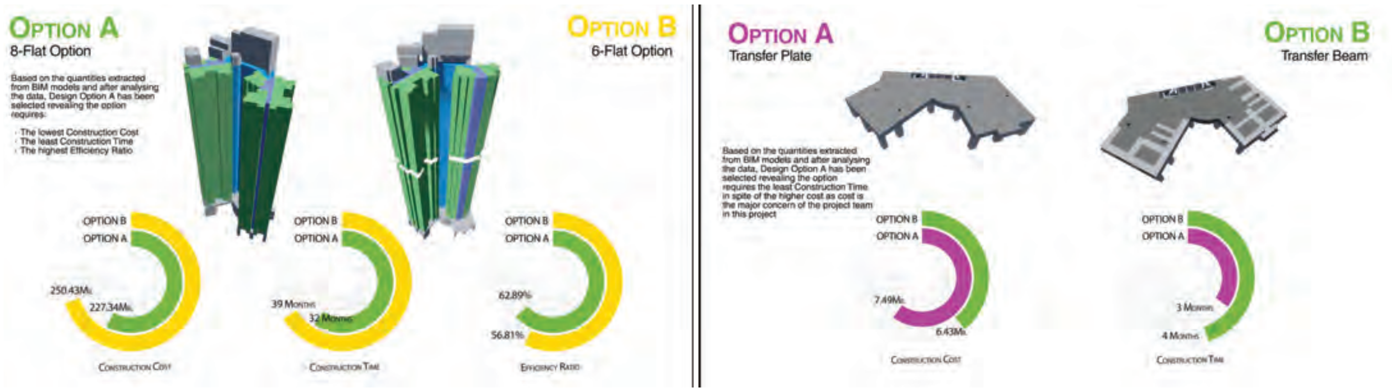

Figure 8. BIM for Value Management and design optimization at Hin Tin Street (Housing Authority)
图8. 显田街发展项目价值管理和优化设计中应用建筑信息模拟系统（来源：香港房屋委员会）

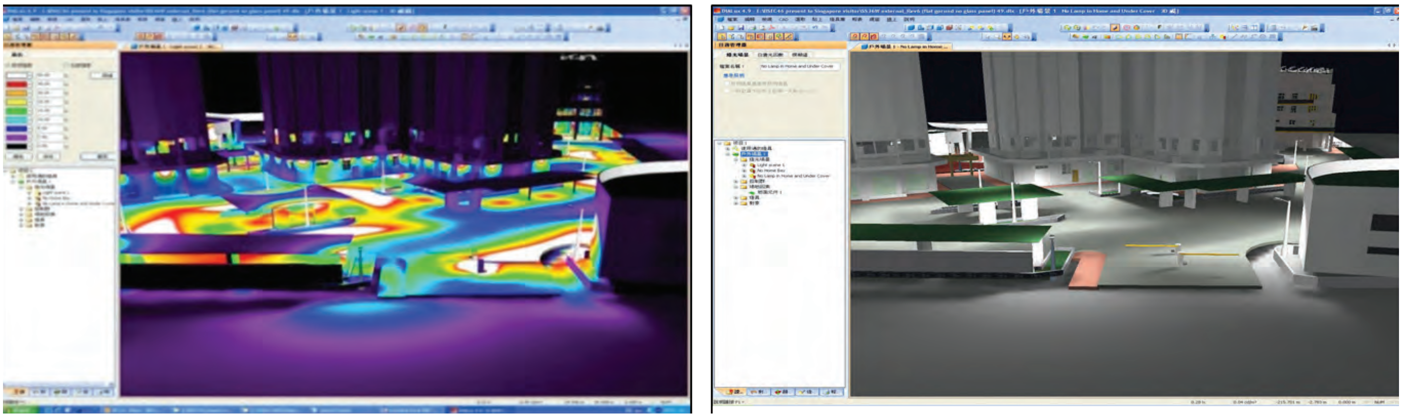

Figure 9. Integrating BIM with lighting analysis software (Source: Housing Authority)
图9. 综合应用建筑信息模拟系统和日照模拟软件（来源：香港房屋委员会）

5.2 Scheme Design Stage

BIM can also be used as a Value Management and design optimization tool at the scheme design stage. In the housing project on Hin Tin Street in Shatin, we have used BIM for value management to compare the merits between a six-flat and an eight-flat per-floor design option, as well as other structural design options to achieve optimum time and cost efficiency for the project (Figure 8).

5.3 Detail Design Stage

Through the integration of BIM and other environmental analysis software, we were able to carry out sophisticated environmental and other technical analyses at detail during the design stage, including lighting simulation, solar radiation and computational fluid dynamics (CFD). For our project at Sheung Shui Area 36, we have integrated BIM with a lighting simulation software to optimize lighting design for energy savings (Figure 9).

5.4 Construction Stage

BIM can also be used for coordination of building services installation and clash detection as well as construction sequencing and safety planning. Tung Tau Cottage Area East is one of our first projects where BIM has been used extensively at the construction stage. It is a project with complex topography comprising three platforms of significant level differences, and requires careful design and planning, in particular for the construction

两方面的表现。过去十年，我们大力推动和应用创新资讯科技系统，包括采用建筑信息模拟系统及地理资讯系统技术，以及最新的无线射频识别科技，从而改善设计效益、提高房委会楼宇的环保效能、提升整个建筑周期的工作质素和安全。

5.1 可行性研究和规划阶段

我们在2014年取得一些突破，开始在地盘规划和可行性研究阶段的工作上应用建筑信息模拟系统和地理资讯系统技术。利用建筑信息模拟系统技术制作的屋村模型，再配合香港的三维立体地形及建筑物图像，我们能够在三维地理资讯系统的环境下进行视觉影响评估、山脊线、了望点和遮蔽分析等一系列研究。这项进展对减少房委会发展项目对环境造成的影响迈出重要的一步（图7）。

5.2 初步设计阶段

在初步设计阶段，建筑信息模拟系统也可作为一项价值管理和优化设计的工具。沙田显田街发展项目的价值管理便应用了建筑信息模拟系统技术比较每层六个单位和每层八单位两种设计各自的优点，也比较了不同的结构设计方案，务求项目在建造时间和成本上均达到最大效益（图8）。

5.3 详细设计阶段

在详细设计阶段综合应用建筑信息模拟系统

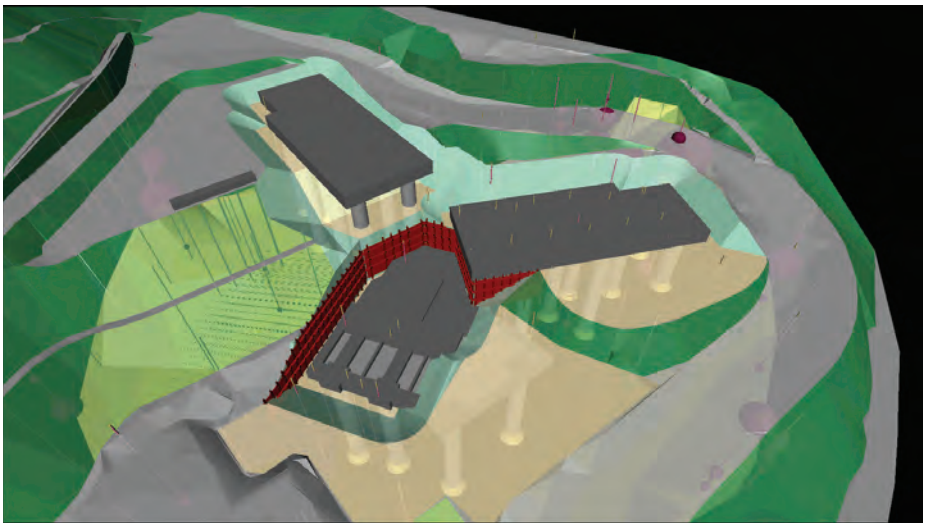

Figure 10. Construction sequence planning for Tung Tau Cottage Area East (Source: Housing Authority)
图10. 东头平房区东的建筑程序规划（来源：香港房屋委员会）

sequence at the site formation and foundation stage. BIM was used as a design and visualization tool to allow the whole team to plan, design and rehearse in a virtual 3D environment to resolve problems well in advance of the construction work (Figure 10).

Most recently, we have integrated the use of BIM and RFID to improve construction performance. For our housing project at Tuen Mun Area 54 Site 2, we have embedded RFID tags into our precast concrete building components during the manufacturing stage and created a cloud base platform to trace the process of delivery and installation of the building components. The objective is to monitor the progress and delivery of the construction work (Figure 11).

5.5 Facility Management and Maintenance Stage

The use of BIM reaches far beyond design and construction stages. Throughout the design and development of the project, a lot of information has been captured into the BIM model including manufacturing and product information, warranty, drawings, cost and quantity. This data rich model is extremely important and valuable for future facility management and maintenance. For "Domain" being our Shopping Centre at Yau Tong, a data rich model has been created at the construction stage to facilitate future facility management. For our project at Sheung Shui Area 36, the underground utilities were carefully documented in the BIM model for future maintenance work (Figure 12).

6. Conclusion and Way Forward

As the main provider of affordable public housing in Hong Kong, we take great pride in meeting the housing need of the people and at the same time providing environment-friendly homes of good quality as we build a harmonious community. We apply sustainable planning principles to foster a Quality Living Environment of Public Housing. We build green and friendly "homes" with sustainable initiatives to meet the rising expectation of

和其他环境分析软件，有助我们进行精细的环境和其他技术分析，包括日照模拟、热辐射及流体力学计算。在上水第36区的发展项目中，我们综合应用建筑信息模拟系统和日照模拟软件，以优化设计，节省能源（图9）。

5.4 施工阶段

建筑信息模拟系统亦可在协调屋宇装备安装、冲突测试、建筑程序和安全规划的工作上发挥作用。东头平房区东是我们第一个在建筑阶段广泛使用建筑信息模拟系统的项目。该项目地形复杂，包含了三个高度差距甚大的平台，必须细心设计和规划，尤其是地盘平整和地基工程阶段时的建筑程序。因此我们利用建筑信息模拟系统作为设计和视觉化工具，让整个团队得以在虚拟环境下进行规划、设计和试验，及早在建筑工程开始前解决问题（图10）。

最近，我们结合建筑信息模拟系统和无线射频识别技术的应用，以提升建筑成效。在屯门第54区2号地盘的房屋项目中，我们在建筑物料生产阶段将射频识别标签内置入预制混凝土预制组件中，并建立云端

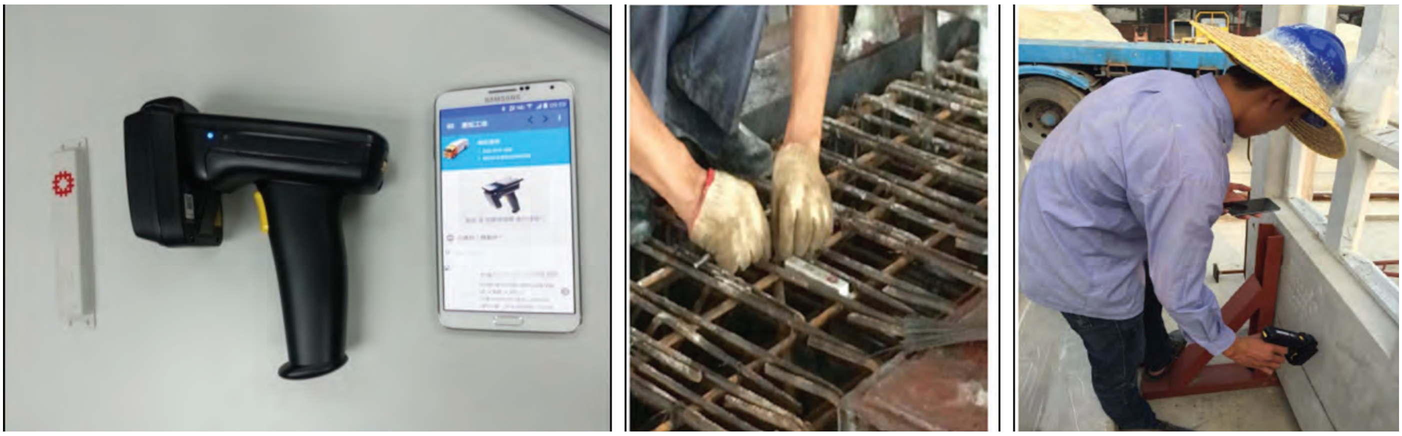

Figure 11. RFID tag and reader (Left) Embedding RFID tags (Middle) Scanning with RFID reader (Right) (Source: Housing Authority)
图11. 射频识别标签及识别仪器（左）内置的射频识别标签（中)运用识别仪器扫瞄射频识别标签(右)（来源：香港房屋委员会）

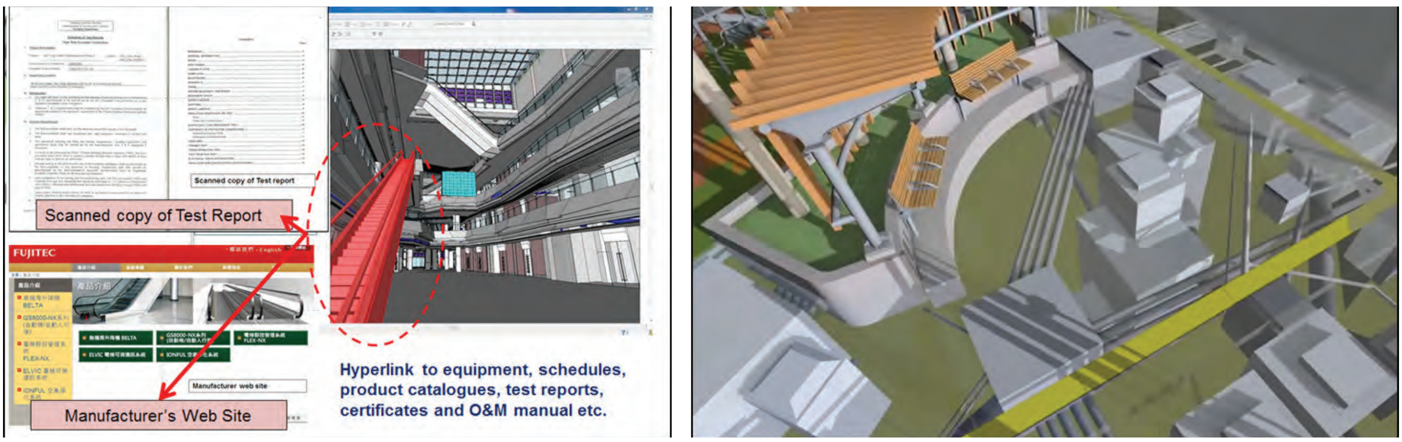

Figure 12. Data rich as-built model for "Domain" Shopping Centre for facility management (Left) Underground utilities at Sheung Shui Area 36 for future maintenance (Right) (Source:Housing Authority)
图12. 油塘商场「大本型」应用大量数据模型进行设施管理（左)上水第36区项目地下公用设施资料以备日后维修保养之用（来源：香港房屋委员会）

the community. Our public housing program has been the keystone to the stability and prosperity of Hong Kong and an anchor of our public administration for more than half a century. HKHA will continue to proactively engage the community and industry stakeholders in the development process to achieve greater efficiency and productivity for continuous improvement, and to provide quality communities and neighborhood that our residents will treasure and be happy to call "home."

平台，追踪建筑组件的运送和安装。此举可监察建造工程的进度和成果（图11）。

5.5 设施管理和维修保养阶段

建筑信息模拟系统的应用亦不仅限于设计和建筑阶段。在项目的整个设计和发展过程中，建筑信息模拟系统模型收纳大量数据，包括生产和产品资讯、质量保证资料、图则、成本及数量。这个包含大量资料数据的模型对日后设施的管理和维修极为重要。以房委会位于油塘的商场「大本型」为例，我们在建筑阶段便已为商场建立一个包含大量数据的模型，以便日后进行设施管理。至于上水第36区的项目，建筑信息模拟系统模型亦已详细记录地下公用设施的资料，以备日后维修保养之用（图12）。

6. 结语和未来路向

作为香港可负担公营房屋的主要提供者，我们在构建和谐社区的过程不但满足市民的住屋需要，又同时为他们提供优质和环保的居所，这个成就令我们深感自豪。我们秉持可持续发展的规划原则，为公营房屋营造优质的居住环境，并采取可持续发展的措施建设环保宜居的家园，以满足社会大众与日俱增的期望。我们的公营房屋计划已成为维持香港稳定繁荣的重要基石，也是超过半个世纪以来香港公共行政的其中一条支柱。在房屋发展过程中，香港房屋委员会继续积极促进社区和业界持份者的参与，以提高效率和生产力，精益求精，缔造优质社区和邻里环境，让我们所建的房屋成为值得居民珍视的安乐窝。

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