Key Considerations for Cleaning and Maintenance Strategies in Dense Vertical Urban Environments | 密集垂直城市环境清洁和维护策略的关键因素

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Liam began his Façade Access (FA) career at Hoare Lea, gaining experience in the design, installation and operation of FA systems in a diverse range of market sectors in the UK and the Middle East. Liam then joined WSP and was responsible for the design and management of a number of iconic projects worldwide. He now fronts D2E's FA division. His involvement in high-rise projects and Dense Vertical Urban Environments include: Battersea Power Station Phases 1 and 3, Wood Wharf Tower, Royal Atlantis Phase 2, Dubai World Trade Centre, 60-70 St Marys Axe, Al Reem Tower, and 261 City Road. 利亚姆．谢波德的外墙通道专业（Façade Access, FA）始于霍尔丽工程顾问公司，并且在英国及中东跟 许多产业合作，累积外墙通道系统设计、安装及作业经 验。他随后加入科进|柏诚工程顾问公司，负责设计和管 理全球多个经典建筑物，目前是法国 D2E 公司外墙通道部 门主管，负责高层建筑和密集垂直都会空间，经手的项 目包括伦敦巴特西电厂第一和第三阶段工程、伦敦伍德 码头塔、巴哈马亚特兰蒂斯皇家塔第二阶段工程、迪拜 世贸中心、伦敦圣玛丽斧街 60 至 70 号，阿联酋奥里姆塔 及英国城市路 261 号等等。

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Abstract | 摘要

The objective of this paper is to raise awareness about the importance of façade access design & how to develop an effective access and maintenance (A&M) strategy. The type and quality of the systems should be considered carefully at the early design stages. This is becoming increasingly important with the rapid growth of dense vertical urban environments throughout the world. The consequence of getting the strategy wrong can have a detrimental impact on the overall appearance and expected lifecycle of the façade, particularly when referring to supertall structures. This paper looks at methods of "best practices and addresses how the risk of a poor A&M strategy can be avoided. By considering A&M at the early design stages of a project, a pragmatic and coordinated approach can be taken to ensure that key system requirements are identified and building interfaces are factored in to the building design to avoid implications at a later date.

Keywords: Access and Maintenance, Building Maintenance, Cleaning and Maintenance, Design Process, Façade, Façade Access

本文目标是提高幕墙出入设计重要性的意识及如何开发出一个有效的出入和维护策略。建筑物设计初期就该仔细考虑外墙出入及维护方案的种类与质量。由于密集垂直城市空间在全球快速成长，使得这一点更显重要。选错方案可能对外墙的外观和寿命造成致命伤害，对超高建筑尤其如此。本论文检视一系列“最佳方案”，并讨论如何处置外墙出入及维护方案不良所造成的风险。通过在设计阶段的早期将出入及维护因素纳入考量，采取务实和合作沟通模式，以确保辨识关键系统要求，应将建筑外立面纳入设计，以避免日后产生影响。

关键词：出入与维护、建筑维护、清洁与维护、设计过程、幕墙、立面开洞

1.0 Overview

As buildings become taller, long term Façade Access and Maintenance (A&M) solutions become increasingly important.

There are several aspects that affect the selection of Suspended Access Equipment (SAE). It is important to realise the implications and identify how they impinge on the overall building design to achieve total access. The main objective of a robust access strategy is to provide access to the entire building envelope.

The type and quality of the systems should be considered carefully at the early design stages. This is becoming increasingly important with the rapid growth of dense vertical urban environments throughout the world. The consequence of getting the strategy wrong can have a detrimental impact on the overall appearance and expected lifecycle of the façade, particularly when referring to supertall structures. This paper looks at methods of "best practices" and addresses how the risk of a poor A&M strategy can be avoided. Careful attention to the key considerations outlined

1.0 概观

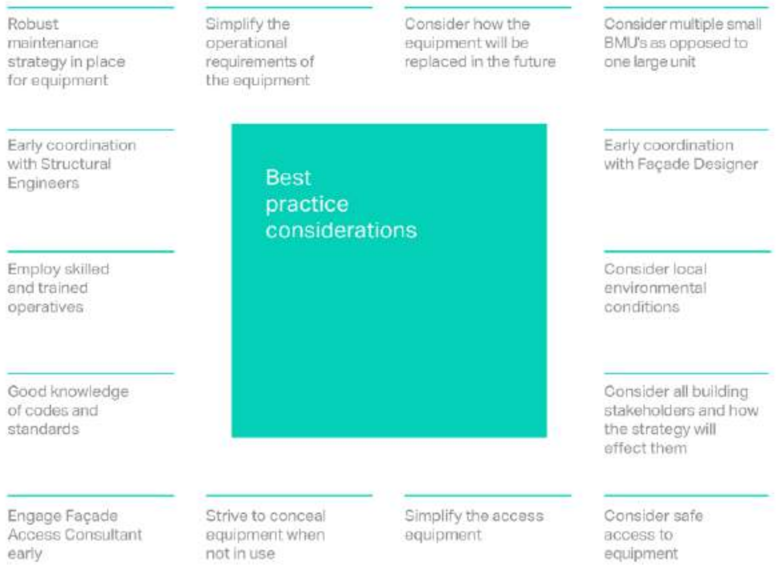
随着建筑高度越来越高，长期立面接入和维护的解决方案变得越来越重要。

这是影响选择悬浮接入设备（SAE）的几个方面。意识到接入策略的影响以及明白策略如何影响整体建筑设计并实现总体接入非常重要。一个成功的接入策略的主要目的是为了整个建筑立面的接入。

随着全球高密度垂直城市环境的快速增长，在早期设计阶段仔细考虑系统的类型和质量变得越来越重要。错误的策略可能对整体外观造成不利影响以及影响预期的立面生命周期，尤其是超高层建筑。本文将着眼于“最佳实践”的方法并讨论如何避免失败的 A & M 决策，以及形成安全有效的 A&M 决策所需考虑的关键因素（图 1）。

2.0 简介

特殊超高层大厦数量不断增长，在今天的市场，制定一个安全、快捷、可靠的出入方案，来保持外墙的外观和建筑状态是当



within this paper should ultimately result in a safe and efficient A&M strategy (Figure 1).

2.0 Introduction

With an ever growing number of unique supertall flagship buildings in today's market, it is imperative to develop a safe, quick and reliable access strategy to retain the appearance and architectural aspirations of the façade. In order to do so, it is advisable that façade access is considered during the early design stages as opposed to an afterthought.

Key factors that affect the selection of access equipment and systems include;

- Health & Safety
- Codes & Standards
- Design Process
- System Requirements – cleaning, maintenance, inspection & glazing replacement
- Building Height and Geometry
- Site Location & Local Climate
- Façade Type – traditional façades, architectural features (i.e., brise solei, bioclimatic, etc.)
- Usability
- Maintainability

3.0 Dense Vertical Urban Environments

Urbanization is happening globally as people migrate to cities in search of employment and economic prosperity. This geographical influx now accounts for over 56% of the worldwide population, while predicting a rise to 68.5% by the year 2050 (United Nations, 2015). This is problematic for town planners and local governments alike, as the rate of housing being developed has to meet the rise in population.

The information displayed in Figure 2 shows the past, present and predicted urban population percentages. It illustrates a rise in all geographical regions, not just regions with emerging economic markets. This surge in urban living has in turn given birth to the emergence of the megacity. This is defined as an urban area populated by over ten million inhabitants. In 1950 there were only two cities capable of claiming this accolade, New York and Tokyo. Today that number is over 22 and steadily rising (United Nations, 2015) (Figure 2).

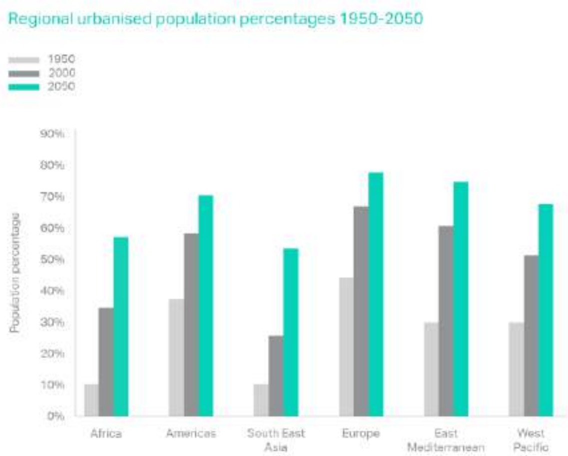


Figure 2. The rise in urban population by geographic region (Source: United Nations)
图 2. 按地区划分的城市人口增长（来源：联合国）

务之急。为达成这点，建议将外墙出入在设计初期阶段而非后期纳入考量。

影响出入设备和系统选择的关键因素包括：

- 健康和安全
- 准则与标准
- 设计程序
- 系统要求 – 清洁、维护、检查和更换玻璃
- 建筑高度和几何
- 场址位置和本地气候
- 外墙类型 – 传统外墙、建筑特色，例如遮阳屏板，生物气候等
- 可用性
- 可维护性

3.0密集垂直城市环境

随着人口往城市迁移，寻找工作和经济繁荣，城市化已成全球现象。地域性迁移人口目前占全球人口 56%以上，预计 2050 年将升至 68.5%（联合国，2015 年）。对 城市规划师和地方政府而言，这件随许多 问题，因为房屋与其他重要公共建设的脚 步，必须跟上人口增长的速率。

图 2 的信息显示了过去、现在和未来预测的城市人口比例。不仅仅是新兴经济体，全球每个地区的城市人口密度几乎都在上升。激增的城市人口孕育了巨型城市，即人口超过一千万的城市。 在 1950 年，全球仅有两个城市纽约 – 纽瓦克和东京获此殊荣。时至今日，巨型城市的数量已攀升至超过 22 个，并继续增长（联合国，2015 年）（图 2）。

This continued growth in urban living has raised demand for high-rise residential housing as this can provide mass housing with minimal footfall. Residents flock to this type of accommodation as it offers inner-city living, close to their work and places of social leisure. As a “knock-on” effect of the rapid population growth in urban environments, new places of work, in the form of high-rise towers, are being developed at a significant rate.

The number of high-rise buildings over 200 meters in elevation has experienced large growth in recent years. For the purpose of this paper, three major high-rise hubs, with varying climatic conditions are discussed: Middle East, Asia and Europe.

There are currently 1,632 of these buildings proposed to be constructed in the Middle East, Asia and Europe by 2020. This number has more than doubled from just 786 since the year 2015 (CTBUH, 2016) (Figure 3).

The local climate can have a significant effect on the façade access. For example, a building in the Middle East will require frequent cleaning as a result of the high concentration of dust and sand in the air. On the other hand, a building in China/Beijing will be subject to a regular cleaning cycle to combat the humid conditions and higher levels of pollution in the air.

The cleaning requirements will vary as a result. To maintain cladding warranties and retain the aesthetic appearance of the façades, buildings in the UAE will be subject to a dry brush clean to remove sand build up, whereas buildings in Asia will require regular wet cleans to tackle stains and dirt build up.

Extreme climates also dictate when the façade access equipment can be used, often reducing the available time to perform the required tasks. Adverse weather implications to consider include: wind – SAE can only operate under certain wind speeds, this varies in alternative parts of the world – and temperature: extreme temperatures can restrict times of operation, ranging from extremely hot façades to snow and blizzard conditions.

Additionally, for geometrically complex buildings, the form can often have a significant effect on wind flow. This coupled with the need for the building maintenance unit (BMU) to operate in vulnerable positions, has historically led to a number of incidents, with equipment being “tipped” even under moderate conditions.

4.0 Design Considerations & Good Practice

By considering A&M early, the design team can focus on coordination to ensure the SAE can be integrated within the building design. A successful A&M strategy is considered to be one that performs efficiently, over a long life span and is concealed from view when not in use.

Early coordination with the design team allows the key considerations to be designed into the building, avoiding potential redesign during the latter stages of the project.

4.1 Codes & Standards

Codes and Standards, both international and local, vary in different regions of the world and have a significant bearing on the type of equipment installed. One of the most widely recognized codes is European EN1808. Key variations between EU codes, Middle East (ME) and Asia include:

城市生活方兴未艾，加上空间普遍有限，占地节省的高层住宅成了最有效的大型住宅方案。由于离工作和社交休闲场所近，提供市内生活圈，人们对这种住宅趋之若鹜。城市人口增长产生“连锁效应”，新形态的高楼工作场所应运而生，开发项目迅速增长。

200 米以上的高层建筑数量近几年大幅增长。本论文将讨论气候条件不同的三大高层建筑枢纽地区：中东、亚洲和欧洲。

目前中东、亚洲和欧洲有 1632 座高层 建筑提案，预计于 2020 竣工。自 2015 年来，此数字已由 786 座翻了一倍多
（CTBUH，2016）（图 3）。

地方气候对外墙出入方案有显著影响。例如，由于空气中的灰尘和沙子浓度较高，中东的建筑物需要经常清洗。另一方面，中国/北京建筑物需要定期清洁，以应付潮 湿和高污染问题。

因此，清洗要求因地制宜。为维持外墙板的担保条件，并保留外墙的美观，阿联酋的建筑需要以干毛刷清洁，去除沙尘。亚洲的建筑则需定期进行湿式清洗，以解决污渍和灰尘积聚问题。

极端气候也决定了外墙出入设备的使用时间，这通常缩限执行任务的时间。恶劣天气的影响因素包括：风速——高空作业平台（SAE）只能在特定风速下操作，且世界各地限制不同。温度：从极热的外墙到下雪及暴风雪气候，操作时间受极端温度的限制。

此外，几何形状复杂的建筑物，其形状常常对风流有显著的影响。加上建筑维护系统（BMU）常需在弱势地点操作，过往曾发生设备被“放倒”而导致事故，即使气候条件相当温和。

4.0设计注意事项和良好实践

若及早考虑出入及维护要素，设计团队可专注协调，确保将高空作业平台纳入整体建筑设计。成功的出入及维护方案要满足有效执行，长期运转寿命，不使用时隐蔽等条件。

及早与设计团队协调可将主要考虑因素纳入建筑设计，避免在项目后期阶段必须重新设计。

4.1准则与标准

国际和本地准则和标准因地区而异，对设备的安装有大幅影响。最受广泛认可的准

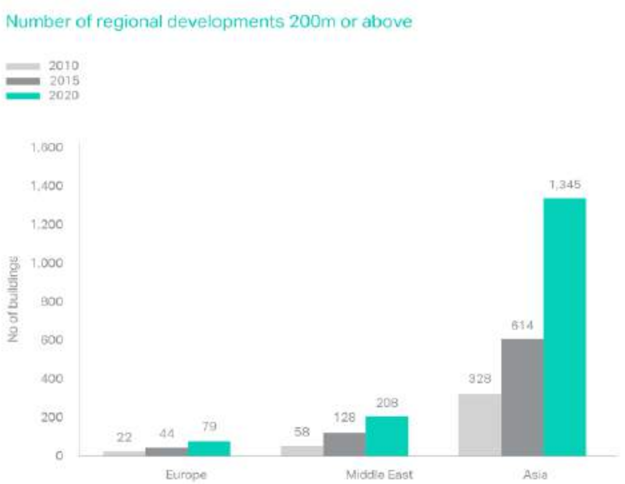


Figure 3. Number of high-rise buildings over 200m (Source: CTBUH)
图 3. 200 米以上的高层建筑数量（来源：CTBUH）

Figure 4. Example: extending cradle accessing deep recess (Source: Cox Gomyl)
图 4. 拓展吊篮触及深凹处示例（来源：Cox Gomyl）

Europe vs. ME

- Both regions design to EN1808; stability ratio, wind loads and general requirements are the same.
- Dubai local codes: 5 pole cable reelers are required as opposed to the 4 pole European requirement.

Europe vs. Asia

- Asia adheres to different codes (HK, China, Singapore etc.) than Europe. HK requires a 3:1 stability factor as opposed to the European 2:1 requirement.
- HK Government projects impose additional measures of safety such as 8mm minimum rope diameters.
- The codes take into account the higher wind loads in Asia, on both the working and parking positions of the BMU.
- Suspended cradle handrails in Asia are higher than in Europe (1100mm height in Asia compared with 1000mm in Europe).

4.2 Health and Safety

The field of SAE offers a diverse range of applications and types. It is not only important that the equipment specified can efficiently carry out its intended task; it must also offer a high degree of safety to its operatives, building users and general public. If working at height cannot be avoided, employers and designers should give collective protection measures priority over personal protection measures.

Practical examples of collective protection using work equipment to prevent a fall include: BMUs, MEWPs, Tower Scaffolds, Gantries and Suspended Cradles, etc., where the operator is working from a stable surface protected by full height edge protection.

Personal protection measures refer to systems that rely on the actions of the individual. This includes rope access and is the last level or resort to be considered if all other measures cannot be accommodated by the design. Should there be no other alternative than to adopt a rope access strategy, designers should ensure the strategy complies with Industrial Rope Access Trade Association (IRATA) guidelines.

4.3 System Requirements

When designing and selecting an access system, it is crucial to identify the core requirements of the equipment early. Designers should strive to ensure the entire external envelope can be accessed, by means of hand contact, for cleaning and maintenance purposes. It is also important to consider the added value the systems could bring such as:

- Glazing replacement
- Plant replacement
- General maintenance tasks (i.e., re-pointing / sealing / lamp replacement / landscape waste removal for bioclimatic façades)
- Façade inspections
- Beneficial use during construction phases
- Life cycle costs and minimizing the cost of cleaning and maintaining the façade
- Efficient cleaning cycle time
- Modern control system to simplify operation and parking
- No physical contact with the building surfaces other than the buffers and restraints
- Minimize the risk of damage to the façade system
- Having the ability to access deep recesses or protrusions
- Limit access through tenants' or residents' property (Figure 4).

则是欧洲 EN1808 准则。欧盟标准、中东标准和亚洲标准之间的主要差异包括：

欧洲 vs 中东

- 两地设计皆符合 EN1808 准则。
- 迪拜当地法规；要求 5 极电缆卷筒，相 对于欧洲 4 极。

欧洲 vs 亚洲

- 亚洲准则和欧洲不同（香港、中国、新 加坡等）。香港要求 3:1 稳定系数：相 对于欧洲 2:1。
- 香港政府工程规定额外安全保护措施， 如 8 毫米的最小直径绳索。
- 建筑维护系统运行和停放位置的准则将 亚洲的高风荷载纳入考量。
- 亚洲悬吊篮扶手要求高于欧洲（亚洲高度 1100 毫米，相对于欧洲 1000 毫米）。

4.2 健康和安全

高空作业平台领域提供多元化的应用方案和类型。重要的是，指定设备不仅要能胜任预定任务，还必须为操作人员、建筑使用者和广大公众提供高度安全性。如果高空作业无法避免，员工和设计师应将集体保护措施视为优先考量，再者才是个人防护措施。

防止坠落的集体保护设备实例包括：建筑维护系统（BMU）、移动式升降工作平台（MEWP）、脚手架、构台和悬吊篮等，作业人员需在设有边缘保护的稳定表面上工作。

个人防护措施指的是依靠个人行为来保护安全。这包括吊绳出入，应将此方法视为最后手段，只在无法使用其他方法时采用。如只能采用吊绳，别无其他选择，设计师应确保符合国际工业绳索行业协会（IRATA）的吊绳准则。

4.3系统要求

设计和选择出入系统时，至关重要的是及早识别核心设备的要求。设计师应尽力确保可以通过手工方式，进行清洁和维护。此外，重要的是要考虑系统带来的附加价值，例如：

- 更换玻璃窗
- 更换植物

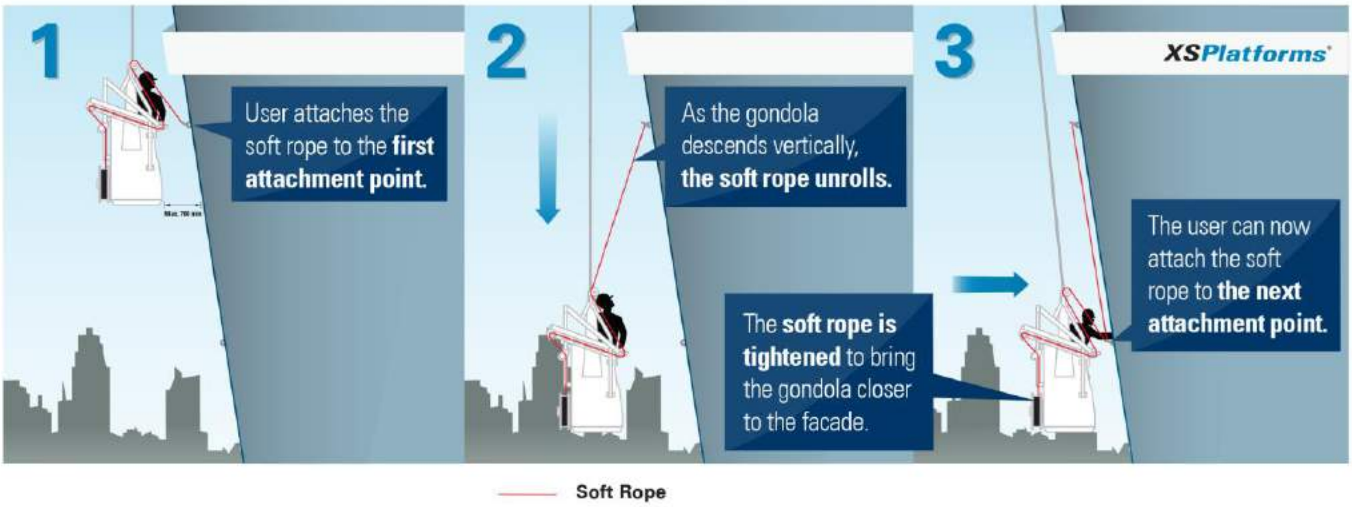


Figure 5. Example: soft rope restraint operation (Source: XS Platforms)
图 5. 软绳限制操作（来源：XS 平台）

A robust access strategy should allow for these key requirements to be achieved in a safe and timely manner.

4.4 Building Interfaces

Building interfaces to consider:

Wheel Loadings – Key aspects such as loadings imposed by the SAE should be designed into the structure early avoiding the potential for redesign during the latter stages of a project. Where possible, a number of smaller BMUs, as opposed to a large single unit, will reduce and spread loadings on the structure. When a large BMU is necessary, consider locating it in a structurally sound area such as above the main core.

Impact Loadings – There is extensive debate within the industry regarding potential impact loads imposed on the façade by suspended BMU cradles. There are various calculations and formulas which can be applied. However, the input variables are subjective and there is no consistent test data available on which the loads can be accurately calculated. It is advisable that early engagement between the façade access consultant and cladding consultant is facilitated to agree maximum impact values and methods of testing to minimize future damage to the façade. These include suitable buffering to the suspended cradle and façade restraint systems to tie the cradle to the façade at regular intervals in order to avoid significant movement in high wind conditions.

Façade Restraints – There are numerous methods of restraining a suspended platform to the façade. These include restraint pins and sockets, mullion guides, and soft rope restraints. The type of restraint system should be considered early to ensure integration can be achieved with the cladding system. The required maximum distance from the suspension point of the suspended cradle to the first level of restraints and the distance between each level of restraints vary in different regions of the world and will be determined by the prevailing codes and standards for the area. In addition to the main restraint system, a soft rope system can be utilized, which allows an additional degree of flexibility whilst negotiating complex façades. A soft rope system facilitates lateral movement and ensures the suspended cradle can access deep recesses and setbacks (Figure 5).

Integration with the Architecture – One of the key requirements when designing an A&M strategy for modern buildings is to conceal the equipment when not in use. As a result of advancements in technology available to virtually model buildings and equipment, designers can work alongside the architect early in the design process to develop innovative methods of minimizing visual intrusion. In addition, advancements in material and construction technology means that SAE are now extremely flexible and bespoke solutions can be developed to accommodate the most challenging buildings.

Modern control systems allow the equipment to be programmed to accommodate complex parking arrangements which can assist in concealing the machinery from site. Although viewed as a positive development in technology, it is important that the systems are not designed to be over complicated, which can result in equipment being left un-parked.

The following figures illustrate bespoke solutions designed to clean and maintain

- 常规维护任务，即勾缝/密封/更换灯具/清理景观废物（生物气候外墙）
- 外墙检查
- 施工阶段使用效益
- 生命周期成本和减少外墙清洗和维护成本
- 高效清洁循环时间
- 现代控制系统，简化操作和停放作业
- 除缓冲和其他限制装置外与大楼实体无接触
- 最小化外墙系统损坏风险
- 具有触及深凹或突出处的能力
- 通过租户或居民终止限制（图 4）。

强效的出入策略应以安全、符合时效的方式来满足这些关键要求。

4.4建筑界面

应考虑的建筑界面：

车轮载荷 – 尽早在结构设计阶段考虑高空作业平台负荷，以避免在项目后期阶段需要重新设计。可能的话，采用多个小型建筑维护系统，而非单一大型单元，如此可减少结构载荷或分散载荷。当需采用大型建筑维护系统时，可考虑定位在结构稳定的地方，如主芯上方。

冲击荷载 – 业内对悬吊式建筑维护系 统吊篮是否对外墙产生冲击载荷有着广泛辩论。虽有许多可应用的算式和公式，然而，输入变项是主观的，而且缺乏一致的载荷测试数据可供精确计算。建议提早与外墙出入顾问和覆层顾问讨论，就最大冲

Figure 6. Example: parked BMU BIM model (Source: XS Platforms)
图 6. 停放中 BMU BIM 模型示例（来源：XS 平台）

Figure 7. Example: operating BMU BIM model (Source: XS Platforms)
图 7. 作业中的 BMU BIM 模型示例（来源：XS 平台
）

geometrically complex façades. Due to innovative parking solutions and early 3D modeling, no equipment is visible when the systems are not in operation (Figure 6, 7 & 8).

4.5 Building Height & Geometry

Building height and geometry have a direct bearing on the selection of SAE. Where practicable, designers should strive to simplify and minimize the quantity of the permanently installed equipment required to clean and maintain the façades.

It is also essential that designers inform the architect and wider design team of the capabilities and limitations of the façade access equipment throughout the design process. This will ensure, within reason, there are no areas of the building which cannot physically be accessed without compromising the safety of the operatives and efficiency of the systems.

A large proportion of buildings with stepped terraces and multiple roof levels can often be cleaned and maintained using traditional telescopic cleaning tools without the need for any access equipment. For a high quality clean, consider employing such methods where practicable up to a maximum of two stories.

Where surrounding ground conditions and landscape design permits, consider the use of temporary mobile elevating work platforms (MEWPs) up to approximately six stories.

For façades exceeding approximately six stories, the most efficient and safe solution is to adopt a BMU strategy. Modern BMU systems are bespoke and can be designed to meet the requirements of diverse building types.

击载荷值及测试方法等达成一致意见，以尽量减少未来外墙的损害。这些措施包括适当的吊篮缓冲，定时以限制系统将吊篮在不用时固定于外墙，以避免吊篮在高风力条件下过度摆动。

外墙限制系统 – 有许多方法可将悬吊平台固定于外墙。这些措施包括限制螺栓和插座，立柱导轨和软绳限制。应尽早考虑采用何种系统，以确保与覆层系统良好整合。吊篮悬吊点到第一级限制系统的距离由当地现行法规和标准规定，因此在世界不同地区各有不同。除主限制系统外，若外墙形态复杂，使用软绳系统可增加灵活性。软绳系统可横向移动，确保吊篮可触及凹槽及缩进处（图 5）。

建筑一体化 – 现代建筑出入及维护方案的关键设计要求之一是，设备在不使用时隐藏。由于先进的虚拟模型建筑和设备技术，设计师可在设计过程的初期和建筑师合作，开发减少视觉干扰的创新方法。此外，材料和施工技术的进步，意味着高空作业平台的灵活性非常高，即使最具挑战的建筑物，也可量身定制解决方案。

现代控制系统可对设备进行设置，解决复杂的停放问题，亦可协助隐藏机器。虽然这被视为优异的技术发展，重点在于系统的设计不应过于复杂，一旦过于复杂，便可能导致设备未妥善收回停放。

以下实例说明复杂的几何形状外墙所采用的定制清洁和维护方案。凭借创新的停放方案和及早建立 3D 模型，不作业时系统是 隐而不见的（图 6-8）。

4.5建筑高度与几何

建筑高度和几何形状对高空作业平台的选择有直接关系。在可行的情况下，设计师应简化并减少清洁和维护的外墙所需的永久性安装的设备的数量。

同样重要的是，在设计的过程中，建筑师应向建筑和设计团队告知外墙出入设备的能力与限制，以确保在合理范围内，系统可在无损于操作安全和工作效率的情况下，接触到建筑物的所有地方。

多数建筑物的阶梯式平台和屋顶可使用传统伸缩式清洁工具清洁，无需使用出入设备。要达到高品质的清洁效果，高度 2 层楼以下的建筑，可尽量在可行的情况下采用这种方法。

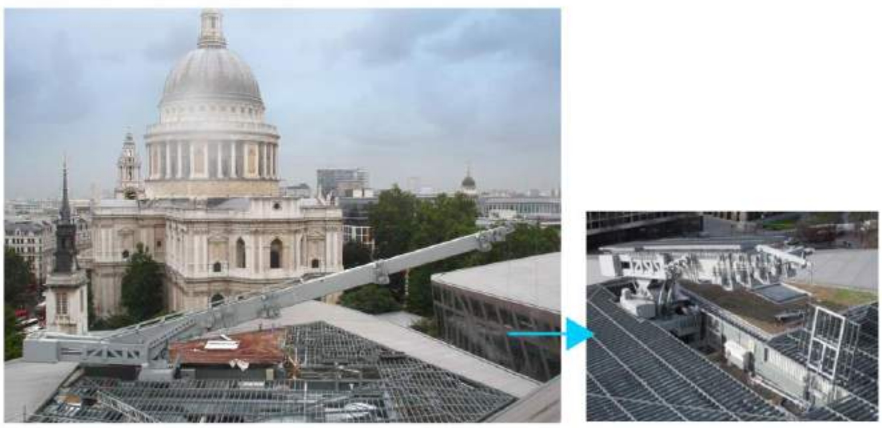


Figure 8. Example: BMU capable of parking below roof (Source: Cox Gomyl)
图 8. 可停放于屋顶下的 BMU（来源：Cox Gomyl）

Buildings in dense vertical urban environments are now being built taller than ever before. To improve cleaning cycle times and add an element of redundancy to the scheme, consider installing a number of smaller BMUs at multiple levels as a measure of good practice.

4.6 Usability

When developing an A&M strategy, the following points should be taken in to account to ensure the equipment is effective "'in-use" and can carry out the desired functions without unnecessary complications;

- Provide a clear and safe route to the equipment – consider the cleaning operatives and their tools, consider access to the equipment for maintenance purposes and how equipment is transported to the cradle. Options to consider include: ensuring the lift extends to roof level or allocating sufficient permanent storage close to the equipment. This will avoid lifting kits up multiple flights of stairs.

- Avoid over-designing the equipment which may be complicated to operate – where practicable, consider specifying tried and tested kits.

- Lifting Requirements – consider any non-routine maintenance tasks the equipment may be utilized for, such as glazing replacement or moving landscape waste. Suspended cradles have a maximum safe working load (SWL), which restricts carrying ancillary loads in the cradle, over and above the operatives and their tools. If heavy cladding is to be replaced from the BMU, consider suitably rated lifting eyes positioned on the jib arm or an integrated winch. This will allow cladding to be hoisted in tandem with the suspended cradle. If the equipment is to be used for landscaping purposes (i.e., maintaining bioclimatic façades) consider the maximum SWL of the cradle and how it will impact on the removal of waste.

- Parking – consider the time it takes to transfer the equipment from the parked position to the operating position; multiple small systems tend to be more user-friendly as opposed to large systems which can be slow and cumbersome to operate, often resulting in the operatives neglecting to park in the designated position.

- Operation and Maintenance (O+M) Manuals – develop comprehensive O+M manuals with clear and concise method statements, risk assessments and operational requirements.

- Training – ensure operatives are adequately trained and have intimate knowledge of both the equipment and the building itself.

- Operating Conditions – consider the most suitable times of day/year when developing the cleaning cycle to minimize the impact of adverse weather conditions, such as heat reflection, to the operatives.

4.7 Maintainability

Modern high-rise buildings, if well maintained, can be expected to function for up to a minimum of 50–100 years before needing to be demolished. The average life expectancy of SAE is approximately 25 years. However, if high quality equipment is installed and regularly maintained the life expectancy will be optimized. Ways to increase the longevity of equipment include:

- Thorough and regular planned maintenance.

- Consider the local climate and ensure the equipment is designed suitably – in extreme climates, such as the ME, consider IP56 motors and control panels with built in fans to combat humidity and a heater to combat low temperatures at night. Poorly considered hydraulic systems in extreme temperatures can lead to catastrophic consequences.

- Consider how the equipment will be replaced after a failure or at the end of its working life; there are several options:

- Hiring a mobile crane – this can be costly and will only provide access up to approximately 180m; in dense vertical urban environments space at low levels is often restricted which further limits their potential use.

- Limiting the size of the equipment and ensuring it can be dissembled in to smaller components offers a greater degree of flexibility as the parts could be transferred via lift shafts and stair cores. From a practicality perspective, this is the preferred solution.

若周围地面条件和景观设计许可，高度 6 层楼的建筑应考虑使用临时移动式升降工作平台（MEWP）。

外墙超过约 6 层楼高的建筑，最有效且安全的方案是采用建筑维护系统。现代建筑维护系统系统可量身定制，满足不同建筑的要求。

时至今日，密集的垂直城市环境中建筑物越来越高。为提高清洗周期和冗余方案，应考虑分层安装小型建筑维护系统。

4.6 可用性

制定出入及维护策略时应考虑下列几点，确保设备处于“可使用”状态，能执行预定功能：

- 制定明确和安全的设备取用路线 将作业人员和其工具纳入考量，考虑设备维修时如何出入，设备如何运到吊篮。选项包括：确保电梯延伸到屋顶水平，或在设备附近的地区安排足够的永久存储地点。这将避免必须抬工具上下多层阶梯。

- 避免过度设计，令操作复杂 – 尽可能指定使用已行之有效的套件。

- 升降要求 – 思考设备可用于哪些非例行维护任务，如玻璃更换或运送景观废弃物。悬吊篮设有最高安全负载量（SWL），限制重复承载作业人员和 工具的重量。若要将覆层从建筑维护系统移除，可考虑使用适当等级的吊环置于吊臂或绞车上，如此覆层与吊篮将协力吊起。如果设备用于环境美化用途，即：维持生物气候外墙等，考虑吊篮的最高安全负载量，以及它对清除废物有何影响。

- 停放 – 考虑设备从停放状态到操作状态需要多长时间，比起体积笨重、操作繁琐的大型机械，多具小型机械往往较容易使用，复杂的作业往往造成作业人员忽略将机械停放在指定位置。

- 操作和维护手册（O+ M） – 制定简单明了的说明手册，包含操作方法、风险评估和操作要求。

- 培训 – 确保作业人员皆训练有素，对设备和建筑物有充分的认识。

- 工作条件 – 规定作业人员清洗周期时考量合适的时间，尽量降低如热反射的恶劣天气的影响。

- If there are no other feasible means of replacement, depending on the location of the equipment and the design of the building, consider removal by means of a helicopter.

5.0 Conclusions

Global urbanization has led to a significant growth in the number of high-rise buildings around the globe. It is currently proposed that approximately 1,600 towers exceeding 200m elevation will be built by the year 2020. With buildings becoming taller, robust façade access and maintenance solutions become increasingly important.

There are many elements that affect the selection of SAE. It is important to realize the implications and identify how they impinge on the overall building design to achieve total access. The main objective of a robust access strategy is to provide access to the entire building envelope for cleaning, general maintenance and glazing replacement.

By considering A&M at the early design stages of a project, a pragmatic and coordinated approach can be taken to ensure key system requirements are identified and building interfaces are factored in to the building design to avoid implications at a later date.

Modern buildings in dense vertical urban environments, if well maintained, can be expected to function up to a minimum of 50–100 years before needing to be demolished. The average life expectancy of the average SAE is significantly less; however, if tried and tested equipment is specified and maintained to a high standard and at regular intervals, the life expectancy will be significantly enhanced.

4.7可维护性

现代高层建筑若维护良好，预计使用寿命可长达至少 50 – 100 年的时间，无需拆除。 高空作业平台的平均使用寿命约为 25 年。然而，若设备安装得当，并定期维护，使用寿命将更长。延长设备使用寿命的方法包括：

- 周全的定期维护计划。
- 考虑当地气候，确保设备设计得当 – 在极端气候条件下，如在中东地区，考虑 IP56 马达和控制面板，内置风扇及暖气，以应对潮湿和夜间低温的问题。在极端温度下，若液压系统设计不良，可导致灾难性的后果。
- 考虑设备故障或其工作寿命结束时如何更换，有几个选项：
- 雇用移动式起重机 – 本选项成本昂 贵，并只能触及约 180 米的高度，在密集垂直城市环境空间中，低层出入往往受到限制，进一步限制了其用途。
- 限制设备大小，确保可以拆解成更小的组件，以提高灵活度。部件可通过升降机井及楼梯间运送。从实用性的角度来看，这是首选的解决方案。
- 如缺乏其他可行的替换方法，考虑以直升机移除，这取决于设备的地点和建筑物的设计。

5.0 结论

随着全球城市化，世界各地高层建筑的数量大幅增长。目前 2020 前竣工的 200 米高 建筑提案约有 1600 座。建筑物越来越高， 稳健的外墙出入和维护方案益显重要。

高空作业平台的选择受许多因素影响。重点在于明白它们对整体建筑设计有何影响，以实现出入毫不受限。一个优异的出入策略主要目标在于整个建筑外围结构的清洁，一般维修和更换玻璃。

在设计阶段的早期将出入及维护因素纳入考量，采取务实和合作沟通模式，可确保辨识关键系统要求，将建筑表面纳入设计，以避免日后产生影响。

密集的垂直城市环境中的现代建筑若维持良好，预定使用寿命可高达至少 50 至 100 年，无需拆除。 高空作业平台的平均寿命相较之下较短，但如果采用行之有效的设备，并以高标准定期进行良好维护，使用寿命预期将大幅提高。

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