DESIGN FOR MAINTAINABILITY GUIDE:

NON-RESIDENTIAL

VERSION 2.0

Design for Maintainability Guide (Non-residential) Revision Log

S/N	Brief description of changes	Revision date
01	First issue	29 May 2019
02	Second issue *Broad summary of changes:* ▪ *Revamp of Smart FM, Security and Landscape Chapters* ▪ *Review of Environmental Services considerations* ▪ *Addition of Robotic & Automation Chapter*	01 Dec 2022

CONTENTS

PART I: INTRODUCTION

Design for Maintainability

Design for Maintainability (DfM) is first step of an effective, sustainable maintenance program, linking maintenance goals and desired outcomes to the design process. It is the practice of integrating maintenance experience in the planning and design process to achieve ease, safety, and economy of maintenance tasks throughout the life of an infrastructure. A lack of maintainability considerations at the onset of a building project often creates avoidable maintenance demands which can lead to higher upkeep costs and manpower needs.

Four important principles dictate the DfM process, which can be coined as the F.A.M.E principle:

(a) *Forecast maintenance* – Designers should understand the impact of their designs and the expected downstream maintenance works, thereby making necessary upstream design provisions.

(b) *Access for maintenance* – Designers should give due considerations for all areas requiring access for inspection and maintenance, thereby making necessary design provisions.

(c) *Minimise maintenance interventions* - Designers should give adequate attention to materials performance and detailing to minimise common and critical defects.

(d) *Enable simple maintenance* – Designers should consciously consider standardisation and prefabricated components to facilitate easy inspection and productive maintenance.

Adopting DfM

The F.A.M.E principle translates itself into via five (5) design considerations, as depicted below.

I. <u>Design Strategy & Collaboration</u>
It is crucial that cross-functional teams take an interest in downstream maintenance, at the project onset.

Key consideration includes:

- Involving FM practitioners and other downstream stakeholders *(e.g. access specialists)* at design.

II. Access for Maintenance

The ability and ease to access, inspect and maintain the facilities is a critical factor for enabling efficient routine servicing and maintenance works. Access provisions must be designed to be safe and provide sufficient circulation and working space for maintenance machines, vehicles or personnel carrying tools, equipment, and component parts.

Key considerations include:

- Adequate provision of access for execution of maintenance tasks including cleaning, inspections, repair and replacement of materials, components, or equipment.
- Design layout gives sufficient circulation and working space.
- Minimise the need for maintenance at height or in confined spaces. Where it is not possible, measures should be put in place to reduce the associated risks.

III. Materials and Finishes

Beyond the aesthetics qualities, designers should consider the suitability of materials in terms of their ability to minimise defects from normal wear and tear (durability) and perform the intended functions throughout the design life. The appropriate use of materials can minimise the frequency of cleaning, repair, and replacement.

Key considerations include:

- Strike a balance between aesthetics, costs, safety, and maintenance needs.
- Select materials that are durable and suitable for the local climate. Consider innovative, high-performance materials that require minimal maintenance.
- Choose materials that are easily available during the life of the facility.

IV. Design and Detailing

Proper architectural design and construction detailing can help to minimise the occurrence of defects and reduce the need for maintenance interventions. The main concerns include having careful detailing to prevent staining, water penetration and premature deterioration, as well as to enable simple maintenance methods and replacement of elements.

Key considerations include:

- Proper and effective detailing to reduce the impact of weather.
- Design enables simple maintenance methods, such as easy diagnostic checks, installation, and disassembly/assembly of components.
- Consider standardisation and modular layout of components, and the use of prefabricated materials/ components.

V. Technology Integration

Smart maintenance and operations, facilitated by technologies, is an essential part of any building. The design intervention required for adoption of technology is influenced by designers.

Key consideration includes:

- Designers must discuss the maintainability outcomes with developers and FM personnel to understand the technology layer.

Purpose

This guide presents a set of design recommendations and best practices to help owners and designers integrate maintainability concepts in the planning and design process. The guide is also a useful reference for facilities managers (FM), service buyers and service providers, who are involved in the design decision process.

This guide is not meant to be definitive nor exhaustive. It also does not address construction quality, operations, and the economic aspects of design decisions. The guide is not intended to override or replace any legal rights, responsibilities, or regulatory requirements.

Scope

The guide is structured by the building disciplines and other important considerations in a non-residential development. These are then generally considered in relation to the five design considerations – design strategy and collaboration, access for maintenance, materials & finishing, design & detailing, and technology integration.

How to use this guide

The designer should indicate "Y", "N" or "NA" in the Y/N/NA column against the design recommendations.

Abbreviation	Denotes
Y	Yes – meet or exceed the design recommendation
N	No – does not meet the design recommendation
NA	Not Applicable – design recommendation is not applicable

The designer should provide a brief description of the provision. If the design recommendation is not met or not applicable, the designer should explain why the recommendation is not considered and whether alternative solution is proposed. Additional notes, references and drawings could be attached to this guide as supporting documents.

As the design objectives differ from one building to another, the recommendations of the guide may not comprehensively address the scope and specific maintenance requirements of a project. The designer should use this guide in conjunction with other applicable codes, regulations, and design guidelines.

An example of how the columns is filled is given below:

A1.	**Access**	**Y / N / NA**	**Description of provision** (Attach relevant drawings or references, etc. where necessary)	**If No or Not Applicable, please explain**
A1.1	**Protruding façade features** Avoid extensive niches, fins and ledges that protrude more than 600mm. If the protrusions exceed 600mm, designers should make specific considerations for safe and easy access.	*NA*		*No protruding features on façade.*
A1.2	**Internal Access** Façade design should promote minor cleaning and repair works to be carried out from within the building, while major repair works can take place from the outside. Use modularised window panels which are not too large (max 750mm) or reversible windows for ease of cleaning from within the building, i.e. within reach of a cleaner's arm and his/her handheld tools.	*Y*	• *Gondola system and elevated walkway access provided*	
A1.3	Access to any part of the façade should not encroach on private spaces or require deconstruction of window units or other building components.	*Y*	• *No encroachment into private spaces*	
A1.4	**Building Maintenance Unit (BMU)** Where BMU is used for façade maintenance, ensure that the BMU is: a) electronically powered and programmable.	*N*		*No BMU system is used. See 'façade access strategy' described in the Maintenance Strategy Report*

1. ARCHITECTURE

A1. ACCESS TO FACADES

Objectives:

Provide safe and easy access to every part of a building's façade and all elements therein (e.g. sunshades, canopies, claddings, lights, signs, and other façade features) – for efficient cleaning, maintenance, and inspection.

A1.	Access	Y / N / NA	Description of provision *(Attach relevant drawings, references, etc. where necessary)*	If No or Not Applicable, please explain
A1.1	**Protruding Façade Features** Avoid extensive niches, fins and ledges that protrude more than 600mm. If the protrusions exceed 600mm, designers should make specific considerations for safe and easy access.			
A1.2	**Internal Access** Façade design should promote minor cleaning and repair works to be carried out from within the building, while major repair works can take place from the outside. Use modularised window panels which are not too large (max 750mm) or reversible windows for ease of cleaning from within the building, i.e. within reach of a cleaner's arm and his/her handheld tools.			
A1.3	Access to any part of the façade should not encroach into private spaces or require deconstruction of window units or other building components.			

A1.	**Access**	Y / N / NA	**Description of provision** *(Attach relevant drawings, references, etc. where necessary))*	**If No or Not Applicable, please explain**
A1.4	**Building Maintenance Unit (BMU)** Where BMU is used for façade maintenance, ensure that the BMU is: a) electronically powered and programmable. b) designed to enable positioning/ suspension of working platforms to reach all exterior surfaces of the building. c) easily accessible via common areas. d) designed with suitable restraints and bumpers to address wind loads.			
A1.5	**Suspended Working Platform** Where suspended working platform (gondola) is used for façade maintenance, ensure that: a) there are provisions for gondola to be safely affixed to the building (e.g. permanent installation points) as well as adequate anchor points for safety ropes and independent anchor for lifelines. b) the gondola can reach all parts of the building facade. c) façade features do not obstruct the operation of the gondolas. Surfaces below protrusions/ cantilevered structures should be reachable and maintainable from the gondola. d) there are adequate safe launching/ landing places for the cradle/ working platform. e) the launching and landing spaces and the access routes to these spaces are located within common spaces and should avoid landing in landscaped areas. f) there is provision of power supply for gondola operations and water supply for carrying out maintenance works. g) ensure spacing between external walls/ structures of adjacent blocks is at least 1.2m to facilitate the safe use of gondolas.			

A1.	**<u>Access</u>**	**Y / N / NA**	**Description of provision** *(Attach relevant drawings, references, etc. where necessary))*	**If No or Not Applicable, please explain**
A1.6	**Ground-based *(Mobile Elevating Work Platform (MEWP))*** Where MEWP is used for façade maintenance, ensure that: a) unobstructed access route and working space are provided, b) access route and working space should be level and designed to take the equipment's load.			
A1.7	**Provision for Use of Ladders** Provide firm and level surface for use of ladders.			
A1.8	**Safety of Maintenance Personnel** Provide safe working environment for the setting up and operation of access systems such as: a) railing, b) anchorage points and/ or lifelines for sliding safety harness, c) eyebolt fixing for rope to secure ladder.			
A1.9	**Air Conditioning (AC) Unit Service Ledge** Provide sufficient working space and safe working environment (e.g. anchorage for safety harness) for maintenance personnel.			
A1.10	Where maintenance access to the ledge is via windows or wall apertures, the size of the openings should allow safe and easy access for maintenance personnel carrying tools, equipment, and component parts. Maintenance activities should not require the dismantling of services and building elements.			
A1.11	Provide safety barriers or guard rails (minimum height of 1m) around the service ledge.			

A2. CHOICE OF MATERIALS & FINISHES FOR FAÇADES

Objectives:

Use appropriate materials and finishes that are resistant to deterioration and exposure to weather elements.

A2.	Materials & Finishes	Y / N / NA	Description of provision *(Attach relevant drawings, references, etc. where necessary)*	If No or not applicable, please explain
A2.1	Adopt materials and finishes that are readily available (i.e. does not require special procurement).			
A2.2	**Paint Systems** Use paint systems that enhance weather protection and lengthen the cyclical period needed for façade re-painting (e.g. paint with anti-stain and self-cleansing properties).			
A2.3	**Fastenings and Fixings** Use materials that are not prone to corrosion or rust e.g. stainless steel or adopt separators to avoid bi-metallic corrosion if different metals are used.			
A2.4	**Outdoor Materials** Avoid materials that are prone to deterioration when exposed to weathering (e.g. plaster or calcium silicate board).			
A2.5	**Sealants** Use sealants that are resistance to staining and bleeding.			

A3. DESIGN & DETAILING FOR FAÇADES

Objectives:

Provide effective design and detailing to promote efficient run-off on façade surfaces to minimise water ponding, penetration, and staining problems.

A3.	Design & Detailing	Y / N / NA	Description of provision *(Attach relevant drawings, references, etc. where necessary)*	If No or not applicable, please explain
A3.1	**External Walls** Provide drip edges to prevent streaks on exterior soffits, walls, and glazed surfaces.			
A3.2	Grade all top surfaces of walls to fall away from external face of walls to minimise streaks on the facade. The coping should overhang the rear side of the walls and comes with drip control to mitigate streaks on the back walls.			
A3.3	**Stone Panels** Stone panels should be mechanically fixed. Avoid the use of adhesive which are prone to efflorescence.			
A3.4	Install stone panels in a way that allows for inspection of its concealed mechanical connections to pre-empt corrosion or defects (e.g. accessible for fibre-optics inspection).			
A3.5	**Metal Cladding and Fixtures** Avoid metal cladding and wrapping around external building components where high pedestrian traffic is expected.			
A3.6	Install metal cladding in a way that allows for inspection of its concealed mechanical connections to pre-empt corrosion, dilapidation and loose or defective fixings.			

A3.	Design & Detailing	Y / N / NA	Description of provision *(Attach relevant drawings, references, etc. where necessary)*	If No or not applicable, please explain
A3.7	**Glazed Surfaces** Avoid inclined glass surfaces, being prone to dirt and dust collection.			
A3.8	Size up external glazing optimally such that glass panels can be transported by lifts to facilitate future replacement from within building.			
A3.9	Avoid the use of non-planar or curvilinear glass surfaces which are difficult to maintain or not readily available in the market.			
A3.10	Ensure that glass (e.g. glazed canopies) is able to withstand the loads imposed during maintenance.			
A3.11	**Glass Parapets** Avoid extensive use of glass parapet walls at outdoor areas as weather stains on glass surfaces are more visible and require more frequent cleaning.			
A3.12	**Weather Control Devices** Incorporate appropriate weather control devices (such as overhanging ledges, copings, and rain screens) to external openings to minimise rainwater ingress. Where wall openings/doors are subject to external weathering, incorporate details such as overhang at the top, and water-bar or threshold kerb at the bottom to minimise water ingress.			
A3.13	**Joints** Provide movement joints to accommodate movement in large continuous areas, or between adjacent building components (e.g. brick wall and concrete column) and dissimilar substrates. The backer-rod material in the joint should be compatible with the sealant used (see SS 677: 2021 Design and Execution of Precast Concrete Slabs and Walls for Buildings).			

A3.	**Design & Detailing**	**Y / N / NA**	**Description of provision** *(Attach relevant drawings, references, etc. where necessary)*	**If No or not applicable, please explain**
A3.14	**Anti-Roosting Measures** Adopt designs that mitigate roosting of birds (e.g. use chamfered or steeply sloped surfaces).			
A3.15	**Planter Boxes** Planter boxes should be accessible for easy maintenance (e.g. located at windowsill level, along service balcony/ corridor).			
A3.16	The location of drainage outlets of planters should not cause stains on building facade.			
A3.17	**Loading/ Unloading Areas** Provide protection to beams and columns in loading/ unloading areas (e.g. colour-differentiated rubberised sleeves) and along service pathways.			
A3.18	**Water Stagnation** Attachments and projections (e.g. air con ledges, maintenance gantry walkways, etc.) on façade should be graded to fall for efficient run-off**.**			

B1. ROOF ACCESS

Objectives:

Design the roof space for safe and efficient movement of maintenance personnel carrying tools, equipment, and spare parts.

B1.	Access	Y / N / NA	Description of provision *(Attach relevant drawings, references, etc. where necessary)*	If No or not applicable, please explain
B1.1	**Direct Access** Provide direct staircase access to main roof areas for maintenance purpose.			
B1.2	**Safety** Provide safety barriers/guard rails (min height of 1.0m) or anchor points for safety harness along the roof perimeter and roof openings (such as skylights and air wells) to prevent fall from height.			
B1.3	Provide minimum 1.5m clear working space (or larger as specified by M&E equipment supplier) between the building edge/parapet wall and M&E installations.			
B1.4	Provide non-slip steps/platforms/catwalks over/along maintenance path to prevent stepping on rooftop services such as piping/ trunking/ conduit.			
B1.5	Provide clear demarcation of maintenance boundaries and access at roof areas.			
B1.6	Provide hoisting facilities and anchorages at the roof for hoisting of equipment after completion of the building.			
B1.7	Where façade extends more than 5m above the roof, provide catwalk or other means of access at the internal side of the façade.			

B2. CHOICE OF MATERIALS & FINISHES FOR ROOFS

Objectives:

Use appropriate materials and finishes that are resistant to deterioration and exposure to weather elements.

B2.	**Materials and Finishes**	Y / N / NA	**Description of provision** *(Attach relevant drawings, references, etc. where necessary)*	**If No or not applicable, please explain**
B2.1	Provide adequate waterproofing to roof surfaces			
B2.2	Avoid extensive use of transparent and translucent roofing materials that are prone to discolouration and deterioration when exposed to weather elements.			
B2.3	Use roofing materials/finishes that can withstand heavy maintenance works (e.g. removing of algae).			

B3. DESIGN & DETAILING FOR ROOFS

Objectives:

Provide effective design and detailing to ensure optimal run-off to avoid water ponding and penetration problems.

B3.	Design & Detailing	Y / N / NA	Description of provision *(Attach relevant drawings, references, etc. where necessary)*	If No or not applicable, please explain
B3.1	**Drainage** Grade all roof areas and open terraces to fall, with adequate gradients, so storm water is directed away from door openings and flow towards rainwater outlets/ floor waste outlets.			
B3.2	Slope the RC roof slab and roof gutters at 1:50 or steeper to facilitate efficient run-off.			
B3.3	Design two-directional fall to improve drainage and to reduce roof slab thickness.			
B3.4	Provide drainage outlet with "debris trap" to prevent choking of the drainage system. Use leaf guards and overflow spouts to prevent water stagnation.			
B3.5	**Expansion Joints** Incorporate adequate expansion joints to prevent cracking and support the vibration of plants and equipment on the roof. The expansion joints should be at regular intervals over large continuous roof areas due to continuous weather exposure.			
B3.6	Fixtures of façade access equipment on the roof should not affect/damage the components of the lightning protection system.			

C1. ACCESS FOR BUILDING SPACES AND ELEMENTS

Objectives:

Ensure that access design and systems enable ease of maintenance to various building elements, vertical spaces, and services.

C1.	Access	Y / N / NA	Description of provision *(Attach relevant drawings, references, etc. where necessary)*	If No or not applicable, please explain
C1.1	**Air Well and Atrium** a) Avoid constricted areas, air wells and atrium which are difficult to access for maintenance. b) Provide suitable access system to maintain the façade/ glazed surfaces within air well/ atrium (e.g. maintenance tracks systems with suspended platforms around large voids and air wells). c) Avoid high volume voids or "soft storeys" with "flying" beams" which do not have easy means of access for maintenance.			
C1.2	**Ceiling Spaces and Height** Avoid lobby areas with high ceiling spaces (e.g. > 5m) which are difficult to access for maintenance.			
C1.3	Where ceilings exceed 5m in height, provide catwalks, elevated platforms and/or unobstructed access route for maintenance equipment and vehicles e.g. scissors lift and mobile elevated platforms.			
C1.4	Provide a service lift of adequate capacity to transport the maintenance equipment and vehicles to for maintaining high ceiling spaces of sky terraces.			
C1.5	**Outdoor Lightings** Lampposts should be safely and easily accessible for lamp replacement (e.g. areas should have firm surface to allow proper deployment of ladders).			

C2. CHOICE OF MATERIALS & FINISHES FOR BUILDING SPACES AND ELEMENTS

Objectives:

Use appropriate materials and finishes to minimise the frequency of cleaning, repair, and replacement.

C2.	Materials & Finishes	Y / N / NA	Description of provision *(Attach relevant drawings, references, etc. where necessary)*	If No or not applicable, please explain
C2.1	**Walls** Avoid spray textured finish on walls and columns where there is heavy pedestrian traffic.			
C2.2	**Floors** Use stain resistant (e.g. mid tone colours) floor finishes in areas with heavy pedestrian traffic such as lift lobbies and common corridors.			
C2.3	Avoid combining metal elements with natural stones to reduce risk of staining associated with metal corrosion.			
C2.4	Use metal (e.g. aluminium-finished) fixtures or doors (with appropriate fire rating, where necessary) instead of timber in areas exposed to weather or damp conditions.			
C2.5	**Exterior Ceiling** Use weather and wind resistant ceiling materials (e.g. metal panels) in areas exposed to weather elements.			
C2.6	**External Signage** Use weather-resistant materials in semi-gloss finish for easy maintenance.			
C2.7	**Vehicle Drop-off Areas** For vehicle drop-off areas, use oil-resistant surface (e.g. pavement or stone) to reduce permanent staining caused by vehicles. Avoid i. porous, soft stone materials. ii. glossy surfaces; or iii. light-coloured materials, in areas with heavy pedestrian traffic.			
C2.8	**Driveway Paving** Avoid the use of rough stone paving for driveway as they are more prone to trapping dirt.			

C2.	**<u>Materials & Finishes</u>**	**Y / N / NA**	**Description of provision** *(Attach relevant drawings, references, etc. where necessary)*	**If No or not applicable, please explain**
C2.9	**Timber** All timber finishes should be kiln-dried and well-seasoned to prevent shrinkage, splits, and deformation. All timber finishes should be treated against water absorption, fungi, and insect attack, including anti-termite treatment, with an approved wood preservative.			
C2.10	**Masonry, Stone, and Tiles** Provide appropriate and compatible sealer/ impregnator to the sides, top and bottom surfaces of stone works.			
C2.11	Where masonry/ stone finishes are used near wet areas, the stone should be appropriately treated (e.g. sealant, admixture, water repellent) and detailed to prevent efflorescence.			
C2.12	**Doors in Waste Collection Points / F&B areas** Provide metal kickplates to doors and door jambs at waste collection points or food stalls/storage areas that are subject to frequent movement by trolleys/wheelie bins.			

C3. DESIGN & DETAILING FOR BUILDING SPACES AND ELEMENTS

Objectives:

Provide effective design & detailing for protection against weathering and enabling simple maintenance.

C3.	Design & Detailing	Y / N / NA	Description of provision *(Attach relevant drawings, references, etc. where necessary)*	If No or not applicable, please explain
C3.1	**Linkways and Drop-off Areas** Provide sufficient roof gradient (min 3˚ slope for flat roof) for efficient water run-off.			
C3.2	Design of linkways, drop off porches, and external corridors should minimise ingress of rain, ensuring at least 50% dry covered passage, e.g. i. Provide drop panels and weatherproof louvers for high volume roof, ii. provide sheltered area or canopy with a depth of at least 2 times the entrance width.			
C3.3	Design of linkways and drop-off porches should be modularised with demountable parts (no welded parts) for ease of maintenance, where required, and to facilitate access for maintenance vehicle.			
C3.4	Provide concrete curb / collar at the base of metal columns to minimise contact with water and reduce corrosion.			
C3.5	Floor slabs should come with removable panels for inspection and maintenance of concealed services.			
C3.6	Grade all exposed floors and flat surfaces to the external drains and scuppers to minimise water ponding.			

C3.	Design & Detailing	Y / N / NA	Description of provision *(Attach relevant drawings, references, etc. where necessary)*	If No or not applicable, please explain
C3.7	Avoid corners and cavities which are inaccessible to cleaning machines.			
C3.8	Provide anchor points for safety harness on linkways and canopies for maintenance personnel.			
C3.9	**Entrance to Building** Provide floor mats with integrated drainage system at the main entrance to reduce entry of water, dirt, and dust into buildings. Floor mat should flush with the floor finishes to prevent tripping hazards.			
C3.10	**Ceiling** Avoid monolithic ceiling design (joint-less with no access to internal services) which are more costly and tedious to repair and maintain.			
C3.11	Use suspended modular ceiling panels that are easily demountable for its easy replacement and maintenance of embedded services.			
C3.12	Where metal ceiling panels are used, they should be designed to prevent sagging and withstand wind loads. Panels should be sized such that they can be easily handled by one person.			
C3.13	**Staircase** Provide nosings (e.g. nosing tiles) to avoid chipping of edge of the steps.			
C3.14	**Expansion Joints** Ensure that sufficient expansion joints are provided to external and internal finishes to prevent cracking, warping, etc.			
C3.15	**Drainage** All concealed drainage, rainwater down pipes should have access openings.			

C3.	**Design & detailing**	Y / N / NA	Description of provision *(Attach relevant drawings, references, etc. where necessary)*	If No or not applicable, please explain
C3.16	Avoid casting rainwater downpipes within wall structures.			
C3.17	Avoid locating rainwater outlets near lifts			
C3.18	**Recessed Floor Lightings** Avoid the use of recessed floor lights that is prone to water damage. If such lights are used, provide drainage to prevent waterlogging.			
C3.19	**Safety of Maintenance Personnel** Provide appropriate warning signs for maintenance crew to prevent stepping on fragile surfaces such as ceiling boards and non-load bearing surfaces (e.g. in voids of service risers),			
C3.20	**F&B Areas** In F&B areas, consider the following for pest management: a) Gaps between pipings and trunkings should be sealed to prevent rodent access. b) Provide rat guards to prevent rats from using piping/trunking to move around. c) Avoid concealed false ceilings above stalls / servery selling or storing raw/cooked food and beverages. d) Install screens (e.g. mesh with openings not exceeding 10mm by 10mm) between stalls, where possible, to limit spread of rat infestation.			

C3.	**Design & detailing**	Y / N / NA	**Description of provision** *(Attach relevant drawings, references, etc. where necessary)*	**If No or not applicable, please explain**
C3.21	**Bin Centre** Provide a clearance of 500mm minimally between the frame of the shutter door and sides of compactor to prevent damage to the property during refuse collection. *Refer to NEA's Code of Practice on Environmental Health (COPEH) for more details.*			
C3.22	**Pneumatic Waste Conveyance System** Adopt PWCS to improve productivity in refuse collection and disposal. PWCS can be fitted with sensors to monitor waste disposal patterns and volume. The frequency of waste collection can thus be adjusted accordingly. a. Provide adequate openings to access PWCS pipings, especially when embedded underground. b. Provide storage space for waste that are unsuitable to be disposed into chutes connected to the PWCS *Refer to NEA's Code of Practice on Environmental Health (COPEH) and SS642: Code of Practice of Pneumatic Waste Conveyance System for more details on the installation and design of PWCS.*			

D1. ACCESS DESIGN FOR PARKING AREAS

Objectives:

Provide adequate and unobstructed access for maintenance personnel and equipment.

D1.	Access	Y / N / NA	Description of provision *(Attach relevant drawings, references, etc. where necessary)*	If No or not applicable, please explain
D1.1	Where services/ plant rooms are within car park, provide service route(s) with adequate headroom and sufficient working space for maintenance vehicle/ equipment. (e.g. access and manoeuvring space for refuse collection truck).			
D1.2	Provide a minimum clear height of 4m for refuse truck road access (from development entrance to the bin centre). *Refer to NEA's Code of Practice on Environmental Health (COPEH) for more details.*			
D1.3	Car park lots should not block the doors of M&E rooms.			

D2. CHOICE OF MATERIALS & FINISHES FOR PARKING AREAS

Objectives:

Selection of materials and finishes should take into consideration stains and wear and tear due to vehicular traffic and exhaust fumes.

D2.	**Materials & Finishes**	Y / N / NA	**Description of provision** *(Attach relevant drawings, references, etc. where necessary)*	**If No or not applicable, please explain**
D2.1	Provide epoxy coating on car park driveway and parking lot for greater durability. Use resilient material (e.g. thermoplastics) for directional and parking lot markings.			
D2.2	The surface material of the driveway and walls should allow easy removal of oil and water stain as well as heavy-duty washing.			

D3. DESIGN & DETAILING FOR PARKING AREAS

Objectives:

Provide effective design & detailing to protect against damages from vehicles and ensure optimal surface run-off to avoid water stagnation.

D3.	Design & Detailing	Y / N / NA	Description of provision *(Attach relevant drawings, references, etc. where necessary)*	If No or not applicable, please explain
D3.1	**Guards and Wheel Stoppers** Use wheel stopper and crash guards to protect columns, walls, and exposed pipes and services near car park lots and driveways.			
D3.2	**Ramps** Provide groove lines on access ramps to facilitate water discharge to the scupper drains on the side of ramps. Avoid deep ring-shaped/circular groove lines, to mitigate water collection which creates potential sites for mosquito breeding.			
D3.3	**Drainage** Provide adequate drain outlets to prevent water stagnation (e.g. scupper drains in the vicinity of wheel stoppers).			
D3.4	Provide cut-off drains with adequate depth and gradient at all areas of the car park that are exposed to weather including: i. the top and bottom of ramps. ii. open/partially exposed staircase (at intermediate landing and/or base of staircase).			

E1. CHOICE OF MATERIALS & FINISHES FOR M&E ROOMS

Objectives:

Selection of materials and finishes for the floors and walls should take into consideration wear and tear and exposure to weather elements.

E1.	**Materials & Finishes**	Y / N / NA	**Description of provision** *(Attach relevant drawings, references, etc. where necessary)*	**If No or not applicable, please explain**
E1.1	**Floors** Use darker tone epoxy topcoat for the floor finishes in service rooms and service corridors.			
E1.2	**Walls** Provide metal chequered plate on walls (up to 1.2m high) for surface protection in service rooms and service corridors that are subject to frequent, heavy wheeled traffic.			
E1.3	**Doors** Provide door kick plate for service rooms that are subject to frequent, heavy wheeled traffic.			
E1.4	Use corrosion-resistant material (e.g. aluminium doors) for service doors exposed to weather or damp conditions.			

E2. DESIGN & DETAILING FOR M&E ROOMS

Objectives:

Provide effective design and detailing to prevent water ingress/egress problems and to enable simple maintenance.

E2.	**Design & Detailing**	Y / N / NA	**Description of provision** *(Attach relevant drawings, references, etc. where necessary)*	**If No or not applicable, please explain**
E2.1	Avoid locating wet areas above critical service rooms (e.g. server rooms, LAN rooms, and electrical rooms). If this is not possible, provide double slab with access and adequate height between slabs for maintenance.			
E2.2	Provide raised kerb at AHU room, water tank room and electrical rooms to prevent water ingress/ egress.			
E2.3	**External AC Screens** Design the sound barriers/ visual screens for air-conditioning equipment in easily demountable, modularised units to facilitate easy access and maintenance.			
E2.4	**Louvres** Provide at least 300mm overhang above louvre vents facing external or set back the louvre vents by 300mm from the building edge.			

F1. ACCESS FOR WASHROOMS

Objectives:

The design and layout of washroom facilities should allow easy access for maintenance.

F1.	Access	Y / N / NA	Description of provision *(Attach relevant drawings, references, etc. where necessary)*	If No or not applicable, please explain
F1.1	**Cleaning Machines and Equipment** Provide at least one service lift to facilitate the transport and access for cleaning machines and equipment.			
F1.2	The washroom entrance should be wide enough for cleaning machines and equipment.			
F1.3	**Circulation** Adopt "doorless" or vestibule entry to facilitate ease of access and improve ventilation.			
F1.4	Design toilet layouts to handle anticipated peak volume traffic and movement of cleaning equipment/robot, especially in commercial developments such as shopping centres, etc.			

F2. CHOICE OF MATERIALS & FINISHES FOR WASHROOMS

Objectives:

Use materials that are resistant to damp and chemical-intensive environments.

F2.	**Materials & Finishes**	Y / N / NA	**Description of provision** *(Attach relevant drawings, references, etc. where necessary)*	**If No or not applicable, please explain**
F2.1	Use moisture impervious, durable (e.g. ceramic tiles and phenolic panels) and cleanable materials for washroom wall and floor surfaces to facilitate cleaning and resource conservation (such as minimising the use of water and cleaning agents).			
F2.2	Use darker tone finishing for floor surfaces closer to the urinals.			
F23	Provide slip-resistant flooring (e.g. slip resistant index of R11) for safety of maintenance workers.			
F2.4	Use metal gratings of sufficient quality (e.g. Stainless Steel 304 for interior use and Stainless Steel 316 for exterior use) to prevent rusting.			

F3. DESIGN & DETAILING FOR WASHROOMS

Objectives:

Provide effective design and detailing to prevent water damages and to facilitate easy cleaning and maintenance.

F3.	Detailing and Design	Y / N / NA	Description of provision *(Attach relevant drawings, references, etc. where necessary)*	If No or not applicable, please explain
F3.1	**Fixtures** Provide wash basins of appropriate size and depth to reduce splashing and wetting of floors.			
F3.2	Use modular and smaller basin mirrors instead of full-span wall mirrors for ease of cleaning.			
F3.3	Use suspended cubicle partitions to facilitate floor cleaning and prevent partition panels from constant contact with damp floor.			
F3.4	Use suitable hinge and lock for cubicle doors – considering the material and weight of doors – to prevent misalignment after prolonged use.			
F3.5	Ensure that the size of recessed/ built-in trash bin can adequately meet the waste capacity demand.			
F3.6	Provide a minimum of 25mm level difference - whether drop or graded - between the corridor and the washroom floor.			
F3.7	Use wall-mounted wash basins, urinal bowls, and water closets to facilitate floor cleaning.			
F3.8	To prevent wetting of floors, use seat bidet instead of handheld bidet spray. For cubicles with handheld bidet spray, ensure floor is graded towards floor traps/drains located at the rear of cubicles to facilitate drainage of water.			

F3.	**Detailing and Design**	Y / N / NA	Description of provision *(Attach relevant drawings, references, etc. where necessary)*	If No or not applicable, please explain
F3.9	Door frame/architrave should be raised above the wet areas and terminate above the floor level. Consider installing sub-frames above the screed level to reduce the chance of water ingress from the wet floor through the masonry works.			
F3.10	**Dispensers** Provide centralised soap dispensing reservoir to support automatic refill of individual dispensers.			
F3.11	Install dispensers' (soap/ hand towel) above the vanity top for ease of replacement/refill. Avoid installing the dispensers behind fixed mirrors/ features.			
F3.12	The dispenser should have a visual indicator (e.g. transparent window) to show the amount of soap/ towel in the dispenser to assist in timely refilling.			
F3.13	Install dispensers (soap/hand towel) / hand dryer close to wash basin.			
F3.12	**Waterproofing** Apply waterproofing membrane to the wall or substrate immediately adjacent or behind a washbasin, sink or similar fixture at a height of not less than 300mm above the fixture.			
F3.13	Waterproofing membrane should be dressed up at pipe penetrations to the finished floor level and dressed down at least 50mm into the floor outlet. Waterproofing membrane should be applied at least 100mm horizontally around the pipe.			
F3.14	Apply waterproofing membrane with an upturn of at least 300mm to create a minimum tanking protection against migration of water to spaces adjacent or below the wet area.			

F3.	**Detailing and Design**	Y / N / NA	Description of provision *(Attach relevant drawings, references, etc. where necessary)*	If No or not applicable, please explain
F3.15	Avoid laying tiles directly onto the waterproofing membrane. As a protective measure against damaging the membrane during tiling, a layer of screed should be laid over the membrane when it is cured.			
F3.16	**Shower Facilities** Provide raised kerbs of at least 100mm at the base walls to act as barriers against lateral movement of water.			
F3.17	Apply waterproofing membrane of at least 1800mm height for the entire enclosure at bath and shower areas.			
F3.18	**Supporting Facilities for Cleaners** Provide a janitor closet/ store on each level for storage of daily-use cleaning tools/equipment, chemicals, and supplies. Storerooms should come with facilities to support washing of cleaning tools, equipment (e.g. large sink for filling and emptying cleaning buckets).			
F3.19	Provide a designated room of sufficient size for cleaners to rest and store personal belongings.			

2. MECHANICAL & ELECTRICAL (M&E)

G1. ACCESS TO M&E INSTALLATIONS ON FAÇADE AND ROOF AREAS

Objectives:

Provide safe and easy access for the inspection and maintenance of M&E installations.

G1.	Access	Y / N / NA	Description of provision *(Attach relevant drawings, references, etc. where necessary)*	If No or not applicable, please explain
G1.1	**Air Conditioning Condenser Unit** Provide adequate working space around the condenser unit to accommodate maintenance and replacement.			
G1.2	**Externally mounted M&E installations** Provide proper means of access for maintenance for externally mounted M&E installations: i. access to LPS installations (strike pads, down conductor tapes etc.) on façade, ii. replacement of lights on the façade as well as light fittings located in high volume spaces (canopy, drop-off porch, sky terrace, etc.), iii. maintenance of other externally mounted M&E installations (e.g. ACMV louver, CCTV, and PA/AV system, etc).			
G1.3	**Lifts** At least 1 lift should preferably land at roof level. Lift should be designed with adequate capacity to transport equipment and parts for replacement and maintenance purposes.			
G1.4	Provide designated access for motor room-less lift (e.g. 'knock-out wall panel') and hoisting beam for servicing and replacement of lift motor.			
G1.5	**M&E Installations on Roof** Provide adequate working space (minimum 600mm) around and between M&E installations at the roof (cooling tower, generator, condenser unit, photovoltaic panels, etc.) to accommodate easy maintenance and replacement.			

G1.	**<u>Access</u>**	**Y / N / NA**	**Description of provision** *(Attach relevant drawings, references, etc. where necessary)*	**If No or not applicable, please explain**
G1.6	**Lightning Protection System** Provide adequate means of access for competent person / professional engineer to inspect and maintain air terminals and lightning tapes at edge of the building.			

G2. CHOICE OF MATERIALS & FINISHES FOR M&E INSTALLATIONS ON FAÇADE AND ROOF AREAS

Objectives:

Use weather-exposed M&E services and equipment that can withstand exposure to weather elements.

G2.	Materials & Finishes	Y / N / NA	Description of provision *(Attach relevant drawings, references, etc. where necessary)*	If No or not applicable, please explain
G2.1	Use IP-rated material for all external signage with lighting.			
G2.2	Use IP-rated and weather-proof material for outdoor M&E devices such as lightings, speakers, cameras, card reader: a) IP65 rated lightings and relevant accessories (transformers/controllers/drivers etc..), e.g. near green wall since exposed to dirt and irrigation. b) External access control equipment (cameras, card reader, etc.) should be IP-rated materials c) Avoid locating fire alarm call points in weather-exposed areas. Alternatively, call points should be made of weather-proof material.			
G2.3	Use corrosion-resistant material for pipes, ducts, louvers, and trays (including their fixing accessories) that are exposed to weather.			
G2.4	Use IP65 materials for M&E services and equipment. Provide IP65 enclosure for control panels, equipment, and components (e.g. electrostatic filters for kitchen exhaust, inverters of photovoltaic installations etc).			

G3. DESIGN & DETAILING OF M&E INSTALLATIONS FOR FAÇADE AND ROOF AREAS

Objectives:

Provide effective design and detailing to enable proper functioning and ease of maintenance for M&E equipment.

G3.	Design & Detailing	Y / N / NA	Description of provision *(Attach relevant drawings, references, etc. where necessary)*	If No or not applicable, please explain
G3.1	**Lightning Protection System** Use natural down conductor (e.g. steel in reinforced concrete structures) instead of exposed lightning tape.			
G3.2	Avoid mounting aluminium tape directly onto calcareous building surfaces (e.g. concrete limestone and plaster) to minimise aluminium corrosion.			
G3.3	**External Air-conditioning Units** Avoid locating air-conditioning units in recesses or enclosed areas (e.g. basements) to mitigate the rejected heat from being recirculated into the equipment			
G3.4	**Lighting on Roof** Provide adequate lighting to access routes leading to M&E installations.			
G3.5	**Cooling Towers** Provide adequate water points and power points close to cooling towers to facilitate cleaning.			
G3.6	Provide effective cooling tower water treatment to prevent corrosion, fouling, and algae growth.			
G3.7	**Photovoltaic (PV) Panels** Provide adequate water points for cleaning of PV panels.			

H1. ACCESS FOR M&E INSTALLATIONS IN COMMON AREAS, PLANTS AND EQUIPMENT ROOMS

Objectives:

Provide safe and easy access to various M&E installations to enable efficient inspection, repair, and replacement

H1.	Access	Y / N / NA	Description of provision *(Attach relevant drawings, references, etc. where necessary)*	If No or not applicable, please explain
H1.1	**Overhead Services** Provide adequate maintenance access space to all M&E installations (isolation valves, ventilation equipment, fire alarms, Extra Low Voltage equipment etc.) above the suspended ceiling			
H1.2	Provide ceiling access panels near floor traps, valves, water heater and air conditioning equipment to facilitate inspection/ maintenance of services.			
H1.3	Provide multi-tier cable trays with at least 150mm access space in between for installation/ maintenance of services cables.			
H1.4	**Prefabricated MEP System** Where prefabricated MEP is used, provide a minimum workspace of 600mm along the centre of the modules. The width of services on each side of the access space should be kept within one arm's length to allow easy reach to all the services.			
H1.5	**Headroom** Provide minimum 2m clear headroom in M&E rooms and access walkways/ service corridors to facilitate safe access and ease of maintenance. Obstructions that result in reduced headroom should be clearly identified and marked.			
H1.6	Provide permanent guarded ladders, catwalks, and hydraulic powered platforms for occasional access to high volume spaces. Such maintenance activities should not require dismantling of services and building elements.			

H1.	Access	Y / N / NA	Description of provision *(Attach relevant drawings, references, etc. where necessary)*	If No or not applicable, please explain
H1.7	Provide space for scaffolding, staging and temporary ladders for infrequent access to high volume spaces. Ensure any fixtures below such spaces can be easily removed to make space for installation of temporary access systems			
H1.8	**Sanitary Pipes** 'Cleaning eye' for sanitary/waste piping system should be clear from obstruction and easily accessible for maintenance. Avoid placing 'cleaning eyes' at high and inaccessible areas. When unavoidable, consider extending 'cleaning eyes' to areas that are accessible for ease of maintenance.			
H1.9	**Lightning Protection System** Provide adequate means of access to inspect and test the test-link panels and earth pits.			
H1.10	**Working Space** Provide at least 600mm unobstructed space or larger (manufacturers' requirements) for maintenance around all M&E equipment for safe maintenance and replacement of equipment.			
H1.11	Ensure adequate working space for the installation and removal of mechanical equipment			
H1.12	**General Access** Provide access panel of minimum 600 x 600 mm for maintenance of building services.			
H1.13	Provide adequate working space within plumbing riser to allow access for maintenance.			
H1.14	**Waste Management** Provide pump truck access to grease traps. Provide extended suction pipe when truck access cannot be provided.			
H1.15	**Safety for Maintenance Personnel** Provide adequate lightings along access walkways and in M&E rooms.			

H1.	**Access**	**Y / N / NA**	**Description of provision** *(Attach relevant drawings, references, etc. where necessary)*	**If No or not applicable, please explain**
H1.16	**Lifts** Distribution boards for motor room-less lifts should be reachable without additional equipment support.			
H1.17	Provide adequate working space to allow lift maintenance personnel to perform major part replacement works.			

H2. CHOICE OF MATERIALS & FINISHES FOR M&E INSTALLATIONS IN COMMON AREAS, PLANTS AND EQUIPMENT ROOMS

Objectives:

Use suitable materials that are resistant to deterioration and exposure to weather elements and dampness.

H2.	Materials & Finishes	Y / N / NA	Description of provision *(Attach relevant drawings, references, etc. where necessary)*	If No or not applicable, please explain
H2.1	Use durable (e.g. metal clad) lighting switches and power sockets in M&E rooms			
H2.2	**Waterproofing** Provide at least IP65 rated lighting switches and power sockets in wet areas (e.g. pantry, water dispenser, washrooms, wash area and potential wet areas in M&E rooms).			

H3. DESIGN & DETAILING OF M&E INSTALLATIONS IN COMMON AREAS, PLANTS AND EQUIPMENT ROOMS

Objectives:

The design and placement of M&E installations should aim at minimising maintenance interventions and enabling ease of repair and replacement.

H3.	Design & Detailing	Y / N / NA	Description of provision *(Attach relevant drawings, references, etc. where necessary)*	If No or not applicable, please explain
H3.1	**Provisions for Maintenance** Provide power points (each point to cover a radius of max. 15m) in common areas to allow use of powered equipment for maintenance.			
H3.2	Provide sufficient water points and power points to facilitate the use of electrical cleaning equipment in washrooms. Socket points should be provided with weatherproof covers.			
H3.3	Provide cleaners' storerooms with utilities supply for washing of cleaning tools and equipment, as well as drainage points and splash proof socket points to facilitate the charging of cleaning tools/equipment.			
H3.4	**Condensation Treatment** Provide proper separation between air-conditioned spaces and non-air-conditioned spaces to prevent condensation. When proper separation is not possible, provide condensation treatment to air distribution grilles / diffusers located in high humid areas			
H3.5	**Prefabricated MEP System** Adopt prefabricated Mechanical, Electrical, and Plumbing (MEP) systems for more productive replacement and installation.			
H3.6	**Mechanical Fans/Exhaust Outlets** Locate mechanical fans/exhaust outlets away from landscaping areas.			

H3.	Design & Detailing	Y / N / NA	Description of provision *(Attach relevant drawings, references, etc. where necessary)*	If No or not applicable, please explain
H3.7	**Labelling** Provide labelling and colour coding of piping and conduits consistent with industry standards (e.g. provide directional signs on pipes for ease of identification).			
H3.8	Provide isolation valves and proper identification to all pipes for easy maintenance.			
H3.9	**High Volume Spaces** Use wall mounted lights and/or suspended lighting systems for rooms with high ceilings (e.g. atria, lecture theatres, reception or lobby areas and stairwells).			
H3.10	**Parking Areas** Locate electrical services away from voids that are exposed to weather elements.			
H3.11	Ensure all electrical outlets are not obstructed.			
H3.12	Provide adequate water and power points at appropriate locations (each point to cover a radius of max. 15m) to facilitate washing and cleaning.			
H3.13	**Sanitary** Provide sufficient sanitary shafts to minimise horizontal piping runs.			
H3.14	**Manholes** Depending on their location, manhole covers should be designed to withstand the required loads. Manholes should be located away from high traffic areas to minimise risk to workers during maintenance.			
H3.15	Where possible, manhole cover/grating should be moveable by one person. Where covers are too heavy to be lifted by one person, lifting tools must be provided.			
H3.16	**Lighting and Ventilation** Provide sufficient lighting and ventilation in M&E rooms and risers that houses heat emitting equipment (e.g. IT switches).			

H3.17	**Flood Mitigation** Provide flood mitigation measures (such as elevated level, kerb, and sump pump) for M&E rooms located at basements.			
H3.18	**Ductworks/ Pipes across Floor** Avoid ductworks/ pipe installations onto M&E room floors to minimise tripping hazards, and damage due to stepping.			
H3.19	**Redundancy Systems** Shutdown maintenance of M&E installations should not affect building's daily operation. Provide redundancy systems and emergency power for shutdown maintenance.			
H3.20	Provide at least 2 lifts for redundancy to avoid downtime during maintenance.			
H3.21	**Lift Motor Room** Install lighting switches near entrances of lift motor rooms, preferably within an arm's length, so that the working space can be lit before entering.			
H3.22	Provide a conducive environment for maintenance personnel in the lift motor room (e.g. well ventilated, provision of fans).			
H3.23	Provide elevated floor level and a minimum 1m overhang above lift motor room doors to prevent rainwater ingress.			
H3.24	**Lift Well** Provide 2-way switch for lift well lighting between the lift well and the lift machine room.			
H3.25	Environmental conditions should not direct water into lift wells.			
H3.26	**Panoramic Lifts** Follow manufacturer's installation advice for ease of access and maintenance.			
H3.27	**Bulky MEP Equipment** Provide removable facade with hoisting platform for replacement of bulky MEP equipment if it cannot be transported via service lift.			

H3.	Design & Detailing	Y / N / NA	Description of provision *(Attach relevant drawings, references, etc. where necessary)*	If No or not applicable, please explain
H3.29	**Air Handling Unit (AHU)** Provide kerb, water point and floor trap in AHU rooms for maintenance of the filters. Proper mechanical ventilation in the AHU rooms should be provided for maintenance personnel.			
H3.30	Direct drainage pipe from AHU into the floor trap instead of terminating the pipe above the floor trap to avoid spillage.			
H3.31	Avoid placing AHU/FCU directly above critical equipment (e.g. server rack, electrical panel, etc.).			
H3.32	Provide auxiliary insulated drain pan with insulated drainpipe for ceiling mounted FCU in M&E rooms. The auxiliary installation must not affect proper operation of the FCU (e.g. hindrance to airflow of FCU).			
H3.33	Provide spring / vibration isolators to equipment prone to vibration transmittance (e.g. ducted FCU)			
H3.34	Provide suitable waterproofing with an upturn of at least 300mm for AHU rooms.			
H3.35	**Chiller** Provide auto-tube cleaning system for condenser tube to avoid fouling.			
H3.36	**Service Risers** Design service risers with adequate width and depth to allow ease of maintenance. (e.g. Minimum width of 600mm should be provided for access to services and components)			
H3.37	Provide handles (e.g. recessed type) for service riser doors			
H3.38	Provide riser doors that can be opened from inside without the need of keys.			
H3.39	Provide load bearing floor in risers that require access by maintenance personnel.			
H3.40	Environmental conditions should not direct water into any shafts and risers.			
H3.41	**Uninterruptible Power Supply** (UPS) Provide by-pass for maintenance of UPS to prevent downtime.			

I. SMART FM

I1.	Digital Readiness and Automation	Y / N / NA	Description of provision *(Attach relevant drawings, references, etc. where necessary)*	If No or not applicable, please explain
I1.1	**Guide to Smart FM** Refer to the 5 – Step Smart process in the Guide to Smart FM to identify potential suitable Smart FM solutions for the project and provide the necessary design intervention to facilitate implementation. For Smart FM solutions selected, specify that interface with a common platform (e.g. Building Management System or Facilities Management System). This will enable seamless operations by the FM team.			
I1.2	**Building Management System (BMS)** Install appropriate computer based BMS to control and monitor M&E equipment such as centralised air-conditioning system, ventilation, lighting, power system, fire protection services, plumbing, security system and landscape irrigation system.			
I1.3	BMS should cater to specific operational needs of building instead of comprising generic specifications from the industry.			
I1.4	Use BMS systems which have analytic features such as monitoring, charting, and trending reports for optimal maintenance planning.			
I1.5	Include alarm notification options (such as SMS) for buildings not operating 24/7.			
I1.6	Provide remote web-based monitoring.			
I1.7	Specify common or non-proprietary protocol (e.g. BACnet, Modbus, Open Platform Communications United Architecture, etc.) for the network backbone of the building management system (BMS). (This will enable standard compliant sensors or equipment to be easily added to the building and be monitored through the BMS)			

I1.	**Digital Readiness and Automation**	Y / N / NA	**Description of provision** *(Attach relevant drawings, references, etc. where necessary)*	**If No or not applicable, please explain**
I1.8	Use common file formats (e.g. xls or csv) for automated and scheduled exported data from any chosen data points. (This will enable exchange of data between systems and allow such data to be analysed by analytics or optimisation software readily).			
I1.9	Place sensors strategically with consideration to access, accuracy, and operation.			
I1.10	**Sub-metering** Divide sub-metering by energy loads and areas. (This will facilitate energy audit, identify maintenance needs and targets to reduce energy use).			
I1.11	**Digitalisation** Use BIM to facilitate integration of relevant information on facility and asset management and better coordinated documentation for maintenance operations.			
I1.12	Ensure BIM model is developed with sufficient details in accordance with Common Data Environment (CDE) Data Standard (aligned with the principles of ISO 1965-2018) for coordination, tender, construction, and handover.			
I1.13	Specify that as-built BIM model must incorporate DfM considerations including maintenance access, design detailing and materials. Specify that the contractor must submit as-built BIM model for consultant's review on DfM considerations before handing over to Facilities Management team.			

I1.	**Digital Readiness and Automation**	**Y / N / NA**	**Description of provision** *(Attach relevant drawings, references, etc. where necessary)*	**If No or not applicable, please explain**
I1.14	**Digital Twin** Specify comprehensive digital building management through digital twin, where appropriate, integrated with sensors and video analytics function. The digital twin should include the following functions where appropriate. a. Visualisation of the premises b. Integration of data visualisation from various building systems (access control, environmental control, telecoms, utilities, facilities usage and etc) c. Assist FM on fault finding and operations when there is a major equipment failure d. facial recognition, pattern or movement recognition and incident reporting			
I1.15	**Power and Data Provision** Provide adequate power and data provisions (LAN cables, Wi-Fi, network switches, server with spare capacity etc.) for future smart FM features.			
I1.16	**Software for Defects Management** Specify digital platforms to manage the progress of defects rectification (including issuance of reminders) and monitor the status of closure of construction defects.			

I1.	**Digital Readiness and Automation**	**Y / N / NA**	**Description of provision** *(Attach relevant drawings, references, etc. where necessary)*	**If No or not applicable, please explain**
I1.17	**Facilities Management System** Specify Facilities Management System, with a common data schema (such as Brick and Haystack) when applicable, to automate FM work processes and improve manpower efficiency. For example, a. Implementation of e-PTW (Permit-to-Work) System to improve efficiency and eliminate paper usage b. Software for Helpdesk Management to manage the process of faults during operation. c. Digital Reporting through cloud platforms for ease of reporting with details, accessing and analysing information. d. Integration with other Smart FM technologies (IoT devices and sensors) to improve efficiency.			
I1.18	**Data Aggregation** Specify data analytics function, including data correlation and decision-making capabilities for appropriate systems. For example a. Data collected will provide trend and impact to relative activity or space a. To provide advance indicative information to predictive next cause of action b. Data will assist to identify waste c. Data will assist to predictive system/equipment performance. d. Reduce or eliminate unnecessary activity			

I1.	**Digital Readiness and Automation**	**Y / N / NA**	**Description of provision** *(Attach relevant drawings, references, etc. where necessary)*	**If No or not applicable, please explain**
I1.19	**Cybersecurity** Provide adequate measures to mitigate cybersecurity threats to BMS and FMS systems, at the planning and design stage. The building owner / developer's IT department or IT consultant should consider specifying these basic cybersecurity requirements: a. Minimum of two network tiers for BMS and FMS – web/application tier ("demilitarised zone or DMZ") and data tier separated by firewall that appropriately configured to block direct access to database from external network. b. Up-to-date anti-virus software in all machines. c. Firewalls to assess communication with 3rd-party services. d. Encryption of critical data at rest (stored data) and data in transit (transmitted data). e. User access shall have Individual user authentication and multi-level grouping to regulate the access. The login authentication to be password protected. f. System audit log or audit trail to record data changes and system access. g. Install two-factor Authentication. For additional reference, these are some international standards on cybersecurity to consider: a. ISO 27001, the International Information Security Standard b. SOC 2 certification, American Institute of Certified Public Accountants. c. IEC 62443, Industrial communication networks - IT security for networks and systems. d. IMDA, Guidelines Internet of Things (IoT) Cyber Security Guide e. Singapore Standards Council, TR64:2018 Guidelines for IoT security for smart nation			

I1.	**Digital Readiness and Automation**	**Y / N / NA**	**Description of provision** *(Attach relevant drawings, references, etc. where necessary)*	**If No or not applicable, please explain**
I1.20	**Software for handing over digitised as-built drawings and O&M Manuals** Specify digital platforms to handover digitised as-built drawings (in editable format to allow future updating by FM) and O&M Manuals to Facilities Management team. Documents must have adequate information to ensure operational continuity from design to maintenance comprising; a. Written description of all the systems operation and control actions to meet the functional requirements of the system, including control strategy and logic diagrams. b. Description of the type of maintenance and the frequency required c. Maintenance checklists d. Instructions manuals and training guides and quick reference procedures/ checklist e. Contact details of suppliers for products used in the project. f. Maintenance Strategy Report for critical elements which minimum includes objectives, policies, intents, requirements, usage, challenges, and strategies which also include various types of maintenance, with repair and replacement strategies			
I1.21	**Space Provision** Design for adequate space provision (rooms and risers etc.) for implementation and maintenance of Smart FM systems.			

I2.	Smart Technologies	Y / N / NA	Description of provision *(Attach relevant drawings, references, etc. where necessary)*	If No or not applicable, please explain
I2.1	**Smart Lighting/Sensor** Specify lighting with sensors to help understand human traffic patterns and optimize/reduce the provision of lighting in low traffic areas. This helps reduce energy use and maintenance intensity. The use of smart lighting systems can provide predictive maintenance functionalities (e.g. light fixture health monitoring) and send out alerts when light fixtures require replacement. Lighting zoning design must facilitate the deployment of sensors to control lighting levels in low traffic areas.			
I2.2	**Smart Bin** Adopt smart litter/ compactor bins with sensors to facilitate on-demand refuse collection Provide adequate power provisions and WIFI coverage to facilitate deployment.			
I2.3	**Smart Washroom** Specify autonomous smart systems with the use of sensors to detect, monitor, and report any defects or situations (e.g. ammonia, people traffic, lighting levels, water usage, hand soap, hand towels, toilet paper and litter bins levels). Data gathered from sensors can be used for analytics such as the determination of peak and off-peak usage and forecasting of cleaning regimes to optimise cleaning crew deployment. Provide adequate power provisions and WIFI coverage to facilitate deployment.			
I2.4	**Digital Pest Control** Adopt smart surveillance/ monitoring systems to detect pests (e.g. rodent tracker) Provide adequate power provisions and WIFI coverage to facilitate deployment.			
I2.5	**Mobile Incident Reporting Management** Adopt mobile app-based incident reporting to facilitate efficient maintenance.			

I2.	Smart Technologies	Y / N / NA	Description of provision *(Attach relevant drawings, references, etc. where necessary)*	If No or not applicable, please explain
I2.6	**Lift Sensors Monitoring** Specify predictive maintenance with the use of sensors. Sensors can detect, monitor, and report any events and potential breakdowns (e.g. mis-levelling of lift car, abnormal travelling speed of lift, abnormal performance of lift door, and condition of lift rope). Data gathered from sensors can be used for analytics such as usage patterns of lifts and forecast the necessary maintenance regimes. Lift mechanics can be dispatched effectively to rectify anomalies and prevent any faulty lift incidents. This system can also be extended to escalators Design specification must capture this requirement.			
I2.7	**Smart Monitoring for Fire Extinguishers** Specify smart systems that provide monitoring of fire extinguishers with sensors. The sensors alert the FM team when the fire extinguisher is missing or has low pressure and due for replacement. Provide adequate WIFI coverage to facilitate deployment.			
I2.8	**Smart Exit Lights** Specify Smart exit lights which conduct periodic self-tests and alerts the FM team on exit lights that are faulty. Design specification must capture this requirement and adequate WIFI provision is required.			

J. SECURITY

Note:

The security design guidelines presented below are suggested to be read together with the following security standards for a more holistic approach on security considerations:

- Guidelines for Enhancing Building Security in Singapore (GEBSS)
- Technical Reference – Video analytics within video surveillance systems – Part 1: Reference architecture and interoperability (TR 69 – 1: 2019)
- Technical Reference for video analytics within video surveillance systems – Part 2: Selection, installation, and benchmarking (TR 69 – 2: 2019)

J1.	**Access and Control**	**Y / N / NA**	**Description of provision** *(Attach relevant drawings, references, etc. where necessary)*	**If No or not applicable, please explain**
J1.1	Locate Central Console in Areas of 24-hours surveillance in a strategic location.			
J1.2	Locate the fire command centre (FCC) and security centre to oversee at least one main ingress/ egress point or critical area. Design the FCC such that the operator can view all alarm signage from his sitting position instead of having to turn round to see the alarm soundings.			
J1.3	Use turnstile with proximity security access passes.			

J1.	**Access and Control**	Y / N / NA	**Description of provision** *(Attach relevant drawings, references, etc. where necessary)*	**If No or not applicable, please explain**
J1.4	**Remote Monitoring/ CCTV** Specify CCTV surveillance technology with motion sensing alert to reduce security personnel. Provide CCTV surveillance at all common and critical areas including but not limited to: • Vehicular entrances and exits (car plate and facial recognition with CCTV cameras that can perform in wet weather conditions, may be considered) • Boundary perimeter (cameras should be positioned so that coverage does not become blocked by landscape) • Lift lobbies • Entries into staircases • Main lobbies • All entrances/exits of the building (including roof) • Last landing of escape staircases • Loading/unloading area • Essential plants, critical equipment, water tanks in open areas and equipment rooms • Washroom entrances • External Driveways with parking potentials • Corridors between various tenancy spaces • Common Services Areas such as Refuse Chute Openings, Bulk Refuse Collection Areas, critical M&E riser shafts, meter chambers and dilution systems			
J1.5	**Visitors Management System** Use computer-based Visitors Management System to record vehicle information via License Plate Recognition (LPR), usage of facilities by specific visitors and provide documentation of visitor's whereabouts.			
J1.6	Specify visitor management system to provide contactless entry for visitors. Provide adequate WIFI coverage to facilitate deployment.			
J1.7	**Natural Surveillance** Natural surveillance of a concealed or isolated route should be encouraged. For example, provide external-facing windows or openings for enclosed stairs or ramps such that they are visible from the surrounding properties.			

J1.	Access and Control	Y / N / NA	Description of provision *(Attach relevant drawings, references, etc. where necessary)*	If No or not applicable, please explain
J1.8	**Facial Recognition System** Specify facial recognition system for the access control at turnstile, door, or lift.			
J1.9	**Uninterruptible Power Supply (UPS)** Provide UPS for security racks to provide backup power in the event of power failure.			
J1.10	**Wireless CCTV Cameras** Design for adequate cyber threat mitigation strategies, especially when adopting wireless CCTV cameras			
J1.11	**Fire Command Centre (FCC) Room** Provide for adequate working space within FCC room for facilities management and security staff.			
J1.12	**Personal Data** Refer to "Advisory Guidelines on Key Concepts in the Personal Data Protection Act" for the management of personal data collected (e.g. through the visitor management system.)			

3. LANDSCAPE

K1. ACCESS FOR LANDSCAPE MAINTENANCE

Objectives:

Provide appropriate access to planters, green walls, and other landscaped features to carry out pruning, maintenance, and replacement safely and efficiently.

K1.	Access	Y / N / NA	Description of provision *(Attach relevant drawings, references, etc. where necessary)*	If No or not applicable, please explain
K1.1	**Access Route** Landscaped areas should have suitable access routes (e.g. pavement, gravel, mulch paths) of adequate width to facilitate maintenance access for workers, equipment, and materials.			
K1.2	Where roofs comprise extensive landscape and Building Maintenance Unit (BMU), ensure that access to the BMU is not obstructed by the landscape			
K1.3	**Vertical Greenery** Frontal access to green walls *(including its sub-system – such as substrate, drainage, irrigation pipelines, supporting sub-frames, gratings, etc.)* For green walls that are less than 2m in height, allow maintenance access from the front via elevated work platforms (e.g. ladder stand platform, mobile tower scaffold, and pole pruner).			
K1.4	For green wall that are more than 2m in height, provide an unobstructed, flat, stable surface of adequate structural capacity in front to allow safe and effective deployment of MEWPs (mobile elevated work platforms). Where the foreground is turfed, the latter should comprise supporting underlayers to withstand the load of MEWPs.			

K1.	**<u>Access</u>**	**Y / N / NA**	**Description of provision** *(Attach relevant drawings, references, etc. where necessary)*	**If No or not applicable, please explain**
K1.5	Rear access to green wall *(including its sub-system – such as substrate, drainage, irrigation pipelines, supporting sub-frames, gratings, etc.)* Provide permanent rear access (e.g. walkways and platforms) with minimally 600mm clear width to all parts of the green wall. The rear access must be designed with edge protection to mitigate risks of fall-from-height.			
K1.6	Mark and identify all designated access/inspection points for maintaining vertical greeneries.			
K1.7	**Growth Lights** Provide direct access to growth lights so as not to damage the greenery.			
K1.8	Design landscape lightings in a manner to prevent them from being covered or obstructed by the plants, so as to make maintenance of the lightings efficient.			
K1.9	**Sky Garden and Planter Boxes** Provide adequate access and working space to planter boxes (including those on building edge) and around trees and tall plants.			
K1.11	**Irrigation** Provide adequate access to irrigation systems for maintenance and replacement. This includes subsurface irrigation systems.			
K1.12	Provide proper access (e.g. pavers, gravel, or mulch paths) to sources of water supply.			
K1.13	**Aquatic Facilities* / Water Features** Provide safe and direct means of access for maintenance of aquatic facilities/water features (e.g. lightings in aquatic facility/water feature). **Note: Aquatic facilities include swimming pools, multi-use spa pools and water playgrounds/interactive water fountains. Refer to NEA's Code of Practice on Environmental Health (COPEH) for more details on design criteria for NEA's licensable aquatic facilities.*			

K1.	**Access**	Y / N / NA	**Description of provision** *(Attach relevant drawings, references, etc. where necessary)*	**If No or not applicable, please explain**
K1.14	**Planters within Aquatic Facilities/Water Features** Design the depth of the aquatic facility/water feature appropriately to allow safe and direct means of access for maintenance of the planters.			
K1.15	Provide adequate space, working area and safe access to pump room, balancing/surge tanks and other pump equipment which serves the aquatic facility/water feature.			
K1.16	**Storage** Provide adequate storage areas for landscape maintenance equipment and materials.			

K2. CHOICE OF MATERIALS FOR LANDSCAPE

Objectives:

Select appropriate plants species and landscape materials to minimise the frequency of maintenance interventions such as pruning, cleaning and replacement.

K2.	**Materials**	Y / N / NA	**Description of provision** *(Attach relevant drawings, references, etc. where necessary)*	**If No or not applicable, please explain**
K2.1	**Plants Selection** a. Select plant species in response to the expected environmental conditions (e.g. choose plants which are appropriate for sunny/ shady areas, waterlogged grounds, high pedestrian footfall areas, elevated edges, sloped terrain, wind conditions etc). b. Avoid planting fruit trees next to walkways, carpark areas, covered linkways and roofs to reduce maintenance due to falling fruits and prevent vector infestation and breeding. c. Avoid tree species with large leaves such as Ketapang to avoid water accumulation.			
K2.2	For greenery abutting aquatic facilities and water features, avoid selecting species with excessive shedding of leaves and blooms. Accumulated plant debris may end up choking the aquatic facility/water feature systems and compromise water quality.			
K2.3	Avoid species with invasive roots system near non-suspended pavement, or for sky gardens and roof-top landscape. Provide root barriers in these areas to prevent them from penetrating into structures, weep holes, drains, and floor traps.			
K2.4	In areas where plant inspection is infrequent and/or cannot be effectively conducted, avoid species that can trap water (e.g. bromeliad, alocasia with thick axils, bamboo with hollow interior stem etc.) to prevent water stagnation and reduce maintenance for pest management.			

K2.	**Materials**	Y / N / NA	**Description of provision** *(Attach relevant drawings, references, etc. where necessary)*	**If No or not applicable, please explain**
K2.5	Plant ferns and hardy ground covers (instead of turf) on sloping grounds or provide slope stabilisation systems for slopes with gradient more than 1:2.5 to prevent soil erosion and minimise the need of frequent maintenance.			
K2.6	Use synthetic turf in areas with high pedestrian traffic or intensive activities (e.g. school fields).			
K2.7	**Test Plots** Prior to skyrise greenery installation, set up plant test plots (mock-up surfaces, etc.) in consultation with skyrise greenery consultants to ascertain the horticulture performance of selected greenery systems and species. The test plots will help to identify suitable species as well as inform building owners/ users on the maintenance needs and strategies.			
K2.8	**Aquatic Facilities/Water Features** Use concealed mechanical S/S bracket systems – instead of adhesive and grout – for stone claddings within water features to minimise the occurrence of efflorescence and stains.			
K2.9	Avoid water features with rough edges and surfaces as they are prone to dirt accumulation and algae growth.			

K3. DESIGN & DETAILING OF LANDSCAPE FEATURES

Objectives:

Provide effective design and detailing to facilitate water drainage as well as to enable safe and ease of maintenance.

K3.	Design & Detailing	Y / N / NA	Description of provision *(Attach relevant drawings, references, etc. where necessary)*	If No or not applicable, please explain
K3.1	Locate plants with similar water requirement within the same vicinity, for e.g. for auto-irrigation systems, provide appropriate zoning for plant beds with common irrigation/water requirements.			
K3.2	**Planters** Provide sufficient soil depth for roots to grow. In general, groundcovers and shrubs require soil depths of between 300mm and 500mm, while small and medium trees (mature heights of 8m to 10m) require between 1m and 1.5m soil depth.			
K3.3	Provide proper drainage to planters (e.g. installing vertical drainage pipes to aid water flow), especially those on concrete surfaces, to account for soil compaction over time.			
K3.4	**Planting on Ground** Planting should be carried out directly on ground wherever possible to reduce the use of planter boxes. If located on true ground, avoid planting on concrete surface to ensure proper drainage.			
K35	**Un-edged Planting Areas** Planting soil should preferably be 50mm lower than unedged planters flushed in level to adjacent hardscape finishes, to reduce soil erosion and spillage onto common and public areas. These are applicable to areas such as true-ground planting, sunken e-deck, roof gardens.			
K3.6	**Outdoor Vertical Greenwall Planter** For outdoor Vertical Greenwall Planter (VGP) above 2m in height, design for height securing features, preferably made of anti-corrosion/rust-proof material, to ensure that the boxes/trays do not dislodge from main wall due to strong winds.			

K3.	Design & Detailing	Y / N / NA	Description of provision *(Attach relevant drawings, references, etc. where necessary)*	If No or not applicable, please explain
K3.7	**General Drainage Considerations** Landscaped footpaths should be at least 50mm higher than the drain for effective drainage. The footpaths should be sloped to fall effectively to the nearest drain.			
K3.8	Ensure runoff from roofs/driplines of buildings does not fall directly onto landscape areas to avoid damage to plants and/or water logging. Otherwise, provide materials to reduce impact (e.g. gravel) or use soil mix with high permeability to prevent water stagnation after heavy rain.			
K3.9	Provide adequate drainage outlets for vertical greenery to avoid stains on façade or water stagnation at the base of the installation (e.g. use drainage trays at the base of the installation). These should be accessible for maintenance.			
K3.10	**Turfs** Avoid planting turf right up to the base of trees to minimise the risk of mechanical damage to tree barks during turf mowing.			
K3.11	Avoid planting turf below tree canopies that do not provide adequate natural sunlight.			
K3.12	Avoid having isolated thin strips of turf or small grass patches that require frequent mowing			
K3.13	Grass surface should be at the same level or slightly higher than adjacent hard surfaces (e.g. pavements) to ease turf mowing.			
K3.14	Provide buffer strips (e.g. gravel) between the turfed surfaces and pavements/footpaths to prevent soil erosion and spillage. Sub-soil drainage should be avoided.			
K3.16	For shrubs planted next to footpaths, offset the planting by 300mm from the edge of the footpath to reduce the frequency of trimming the shrubs due to encroachment into the footpaths.			
K3.17	**Growth Lights** Design growth lights to the appropriate IP rating.			
K3.18	**Sky Gardens** Allow adequate exposure of plants to direct sunlight to avoid etiolation or leaning of trees beyond the edge of building in search of light.			

K3.	**Design & Detailing**	Y / N / NA	Description of provision *(Attach relevant drawings, references, etc. where necessary)*	If No or not applicable, please explain
K3.19	Where landscape is located near building edges, provide edge protection (e.g. guardrails, lifelines, or anchor points) to mitigate risk of fall-from-heights.			
K3.20	Trees should be adequately secured to withstand strong wind and mitigate risks of uprooting.			
K3.21	Provide sufficient space for anchor staking/guying especially for young/recently planted trees where the root system has yet to develop.			
K3.22	Avoid planting shrubs beyond parapets so that maintenance personnel do not have to lean over the parapet to reach the foliage.			
K3.23	The floor slab should be sloped towards the drainage outlet with adequate silt control system. Waterproofing membrane should be properly installed around the drain opening so that water drains off the waterproofing membrane to the roof outlet. Plants should not be allowed to grow into scupper drains.			
K3.24	Provide adequate sources of water supply (e.g. taps) that are separated from the irrigation system in landscape areas.			
K3.25	The finished level of sky gardens should be lower than adjoining indoor threshold to avoid rainwater ingress.			
K3.26	In instances where sky gardens finished level is higher than the indoor finished level (e.g. retrofitted roof garden in an existing building), provide kerbs at thresholds or cut-off drains with adequate capacity to minimise rainwater ingress.			
K3.27	Provide adequate distance between tall plants and lamp/CCTV posts, footings to secure posts, or mount the posts on footpaths where possible, to avoid damage from the roots.			
K3.28	Provide concrete footing or mount electrical isolators (IP65) for landscape lamps at least 10cm above ground level to mitigate the effect of soil settlement. Dislodged or sunken isolators caused by soil settlement are prone to damage during grass cutting.			

K3.	**Design & Detailing**	Y / N / NA	Description of provision *(Attach relevant drawings, references, etc. where necessary)*	If No or not applicable, please explain
K3.31	**Waterproofing** Provide adequate waterproofing system (for e.g. a combination of cementitious and membrane water proofing may be considered) at landscaped areas and planters. Waterproofing should be root resistant and/or alongside a suitable root barrier.			
K3.32	**Tree Wells & Gratings** Tree well gratings must be durable and weather-resistant with effective drainage to avoid waterlogging issues. Gratings should be designed to prevent litter from entering the tree well, facilitate inspection access (i.e. designed with moveable modular segments, which can be handled by one maintenance personnel, etc.) to the tree well and allow installation of tree support system and future tree growth in girth.			
K3.33	**Irrigation System** Adopt automatic-irrigation systems with rain sensors. For outdoors, ensure that the system can be automatically shut down during rainy days to save water. Ensure that landscape under sheltered areas remain irrigated even on rainy days to maintain plant health and quality.			
K3.34	Where water supply to the irrigation system comes from rain harvesting systems, sump pits with strainers should be provided to prevent blockages from debris and minimise frequent maintenance to the irrigation network.			
K3.35	Where non-potable water is used for landscaping, label it appropriately and secure it for health, safety reasons.			
K3.36	Design landscape/water features to avoid water stagnation during long periods of non-operation (e.g. install irrigation pipelines at a gradient)			

K3.	Design & Detailing	Y / N / NA	Description of provision *(Attach relevant drawings, references, etc. where necessary)*	If No or not applicable, please explain
K3.37	**Aquatic Facilities/Water Features** Use concealed bracket systems for stone claddings within water features to minimise the occurrence of efflorescence and stains on grouting.			
K3.38	Avoid water features with rough edges and surfaces as they are prone to dirt accumulation and algae growth.			
K3.39	**Underwater Lighting** Provide adequate cable length for underwater light fixtures to allow for maintenance above the water level.			
K3.40	Design all underwater lights to have IP68 rating.			
K3.41	**Pumps and Filtration Equipment** Avoid submersible pumps and filtration equipment where possible.			
K3.42	Provide backwash for filters. A non-corrosive removable catch screen/overflow strainers should be provided to prevent dry leaves and rubbish from getting into pump and balancing/surge tank. Precautions to be taken in design to avoid pump overheating due to pump suction being choked with debris.			
K3.43	Provide adequate lighting and ventilation to pump rooms.			

4. Other Good Practices

L.	Design Collaboration	Y / N / NA	Description of provision *(Attach relevant drawings, references, etc. where necessary)*	If No or not applicable, please explain
L1.	**Design Brief** Provide a clear design brief for maintenance performance and operations.			
L2.	**Collaborate with FM and Other Stakeholders** Engage FM practitioners throughout the planning and design phase for their inputs and review of design drawings and specifications.			
L3.	Collaborate with relevant WSH consultants to review the necessary safety provisions for all areas that require maintenance access.			
L4.	**Virtual Reality** Conduct virtual walkthrough of the digital building model to identify potential maintenance issue during design.			

M.	Building Records	Y / N / NA	Description of provision *(Attach relevant drawings, references, etc. where necessary)*	If No or not applicable, please explain
M1.	Prepare as-built drawings (showing equipment layout, routing of M&E services, concealed services, and landscape) and O&M manuals for end-users' future reference and maintenance purposes. These documentations should be regularly updated and kept for record purposes. All maintenance personnel should be made aware of such records. The records are preferably in both hard and soft copies, with proper dates of updating.			

N.	Innovation	Y / N / NA	Description of provision *(Attach relevant drawings, references, etc. where necessary)*	If No or not applicable, please explain
N1.	**Self-cleansing Facade** Adopt façade materials with self-cleansing properties (e.g. titanium dioxide coating) to reduce the frequency of façade cleaning.			
N3.	**Washrooms** Use tiles, basins, urinals, and WCs that are infused/coated with anti-stain material or self-cleaning protective coatings (e.g. fluoropolymer coating) to facilitate cleaning efforts and eliminate the problem of tough stains and graffiti.			
N4.	Provide anti-odour tiles that can address foul smell such as urine spillage on the floor.			

O. ROBOTICS & AUTOMATION

O1. Introduction

This chapter shares the design principles and considerations in adopting robotic solutions for operation and maintenance tasks. It presents a list of good practices for building owners/developers/designers to consider at planning & design stage to allow a safe and conducive environment for both people and robots to carry out their intended activities efficiently. Holistically, there are two design approaches towards achieving this.

i) Design of Robots (DoR)

DoR is a process that explores how robot design can be influenced by the spatial design data of the workspace and its interior fittings to help the robot fit into its intended deployment area better for improved robot performance. Some methods involve pre-mapping the workspace to establish typical hazard locations and redesigning existing robot models e.g. robots' wheels to circumvent or minimise the impact of such obstacles during its work.

DoR looks into the design of the technological aspects of the robot, ensuring that the robot meets the task requirements in the environment it is expected to perform. DoR follows conventional approaches in that robots should be capable of adapting to the environments to carry out their stipulated tasks.

ii) Design for Robots (DfR)

On the other hand, DfR involves passive modifications to the environment or robot's workspace to enable improved performance of service robots. It also reduces the complexity and potential cost of robotic systems to operate in highly unstructured environments, while ensuring their efficiency and safety. Strategies to adapt the built environment often entail catering for physical affordances and providing distinct visual aids for navigation or obstacle detection, or even streamlining obstacles in robot's path to minimise disruptions in their work.

Fig 1-1 A scrubbing robot at Changi Airport

Fig 1-2 A cleaning robot at BCA Academy

Fig 1-3 A cleaning and security robot at Heartbeat@Bedok

O1. Introduction

The scope of this guide places emphasis on DfR. DfR strategies are broadly categorised under the five robot-inclusive design principles – i) safety for the robot, environment, and people, ii) activity, iii) accessibility, iv) observability, and v) manipulability, which are elaborated in the next page. These changes are not meant to override but instead to complement existing human-centric spatial design standards. Human-centric guidelines are to take precedence, should any DfR guidelines clash with those of human ergonomic principles.

Building owners should design/modify the robot's working environment based on the type of robot and its task scope.

The timeline below presents the trend of how robotic deployments are expected to be implemented within buildings. In the Application stage, various robot models are implemented in existing built settings to gain data and feedback. Adaptation is the implementation of updated robot design in existing buildings based on data obtained from the Application stage. With better understanding of the robots' behaviour in various built settings, we can achieve an improved integration of robots into new built environments in the future through better planning.

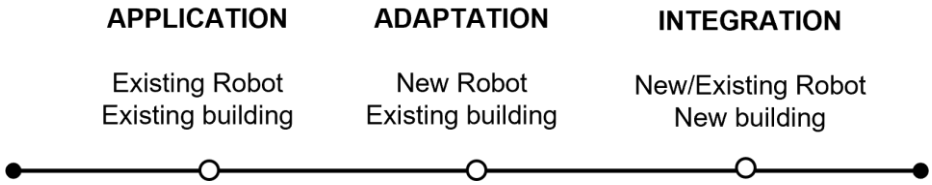


Fig 1-4 Security robot at Jewel Changi Airport

Fig 1-5 Concierge and security robot at Jem

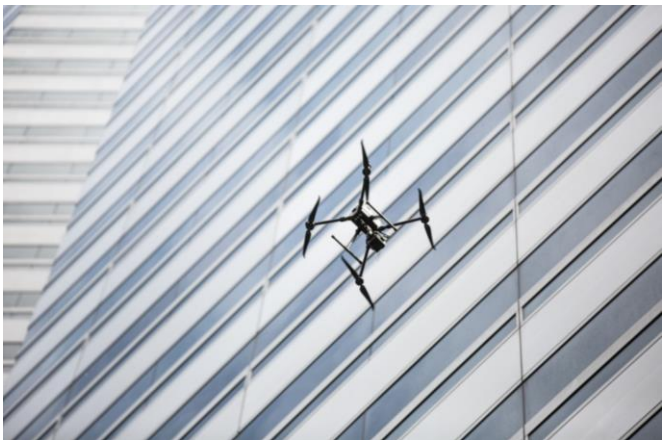


Fig 1-6 A drone carrying out façade inspection of The Gateway

O2. Robot-inclusive Design Principles

Five robot-inclusive design principles are developed for better planning of the built environment: **safety, accessibility, activity, observability, and manipulability**.

i. **Safety** is the overarching principle, serving as a foundational base to the other four. Safety looks into the safety of the robot, people, as well as the environment.
ii. **Accessibility** involves maximising the robot's area coverage of its workspace and providing barrier-free access and connectivity for robots to travel to and within their workspace to carry out its tasks.
iii. **Activity** aims to provide an efficient and streamlined integration of workspaces between people, goods, and robots.
iv. **Observability** works towards improving the robot's spatial environment in terms of accuracy in visibility and perception of its surroundings for navigation and carrying out tasks. It can also refer to traceability and localisation of the robot by a fleet management system.
v. **Manipulability** strives to enhance the robot's ability to move or rearrange objects in its given environment with precision, performance, and speed using its end effectors.

Important to note that these robot-inclusive design principles complement the five key design principles of DfM – (i) **design and collaboration**, (ii) **access for maintenance**, (iii) **choice of materials and finishes**, (iv) **design and detailing**, and (v) **technology integration**.

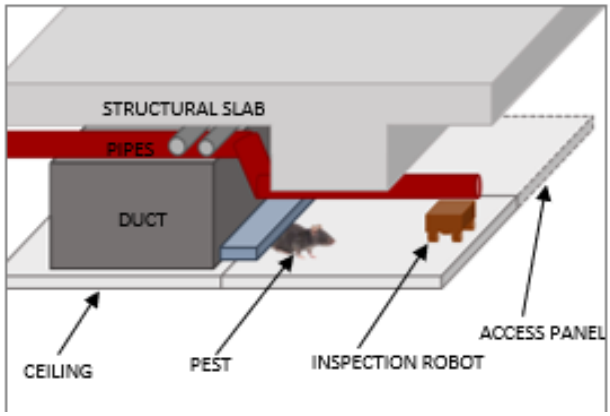
Given the DfM context of this guide, we have clustered DfR considerations under these latter DfM principles rather than the robot-inclusive design principles, as elaborated in the next few pages.

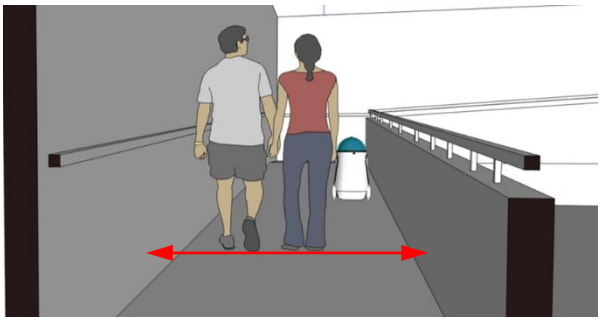
O3. DFM CONSIDERATIONS FOR R&A ADOPTION

O3.1 Design Strategy & Collaboration

Objectives:

Engage relevant parties and stakeholders at the planning and design stage to discuss and understand the robotic deployment plan for improved efficiency of downstream maintenance regimes

O3.1	Design Strategy & Collaboration
O3.11	**Robots of Use** Determine the types of robots to be deployed in the building, their tasks, any components on the robot and intended site of deployment, as illustrated in Table 1 and 2 below. This should include possible future robotic adoption too. Some of the considerations include: • Area coverage • Point-to-point travel • Shared spaces between multiple types of robots and people (e.g. staggering timings of deployment during periods of heavy human traffic) • Shared spaces between robots and building services (e.g. ceiling inspections) **Table 1** – Robot's work scope **Scope** Function of robot | Site of Intended Deployment | Level of Autonomy | Task Requirements **Table 2** – Robot's components **Components** Locomotion Mechanism | List of Sensors | Dimensions (W*L*H), Maximum Reach | Weight & Payload | Manipulators  Fig 3-1 Coordination and proper placement of building services housed within the suspended ceiling during planning stage to facilitate robotic inspection downstream.

O3.1	O3.1 Design Strategy & Collaboration
O3.12	**Robots' Workspaces** ▪ Define robots' workspaces – i.e. spaces where robots share the same zones with people or building services and where they do not. Designate circulation areas with minimum required clear widths and heights where robotic deployments are intended, for e.g. using digital twin to review robots' navigation ▪ Consider design of corridors and spaces to be as contiguous as possible, so as to improved efficiency and minimize tough to reach edges ▪ Consider signage, information boards, and safety training for users of the space where workspaces overlap so they are informed of the robots' existence and nature of operations  Fig 3-2 Upstream design on width of ramp based on envisaged human traffic flow and robots deployment  Fig 3-3 Signage on the robot / robot's interaction with digital display can help to inform users on its existence, movement and nature of operations
O3.13	**Integration with Building Infrastructure** Plan for technology integration with the building control systems (e.g. feedback captured by FM system must be able to communicate to building infrastructure information system and for subsequent dispatch alert to robots) and fleet management (e.g. Robotics Middleware Framework (RMF) for lift integration communication with robots for inter-floor travel) to create a communication network system between the robots, IoT devices and building infrastructure For requirements on integrating robots with lifts, automated doors, please refer to *TR93:2021 – Data exchange between robots, lifts, and automated doorways to enable autonomous operations*

O3.2 Access for Maintenance

Objectives:

Review infrastructure conditions (e.g. obstructions) to allow safe navigation, good connectivity between spaces, and adequate access for the robot, to maximise its accessible area.

O3.2	Access for Maintenance
O3.21	**Spatial Considerations for Robot Deployment** Ensure sufficient manoeuvring space for robots *(i.e. account for its dimensions including length, width, height, weight, payload, turning radius and reach)*, including space for any effectors, actuators, or attachments on the robot: • Along circulation spaces from storage or deployment points to their workspace • Within the robots' workspaces  *Image by Alex (Jewel Changi Airport)* Fig 3-4 Waste management robot deployed at Jewel Changi Airport. Wide circulation spaces to accommodate movement of waste collection bins attached to the robot.

O3.2	Access for Maintenance
O3.22	**Navigation** Design layouts to allow efficient movement of robots *(e.g. clearance)* so that they can take the shortest and most direct paths. For e.g.: • Where robots are not designed to open doors on their own, avoid locating doors along the robot's pathways as these would limit their access • Where there are level differences within a floor, consider the use of ramps, if available, for robots to move between the levels seamlessly • Where robots are moved between floors using lift, there should be sufficient room for manoeuvrability within the lifts • Where robots are deployed for ceiling inspection, i) provide proper access panels for lifting and placing the robots on the ceiling ii) avoid placing (e.g. bait trays) or laying down items (e.g. cables/trunking) on modular false ceiling panels as these inhibit movement of the robots • Where drones are deployed for facade inspections, provide designated points for drones to launch and sufficient buffer from building facade to facilitate photo taking using drones (i.e. avoid situations like limited line of sight, out of sight etc.)  Fig 3-5 Ramps provided for wheelchair bound individuals can double up for robots to move  Fig 3-6 When deploying drones for façade inspection, provide designated points for drones to launch
O3.23	**No-go zones** Set up virtual wall barriers *(e.g. using external compatible device or within robot's internal maps)* or provide safety indicators at no-entry zones to prevent robots from entering. Common no-go zones include lifts (i.e. those not for inter-floor travel), staircases, escalators, or areas with steep gradients or level changes

O3.3 Materials & Finishes

Objectives:

Selection of materials and finishes should (i) maximise the robot's detection and perception ability of its surroundings as well as its smooth traversal during navigation, and (ii) be durable to withstand collisions with robots.

O3.3	Materials & Finishes
O3.31	**Ground Surfaces / Walls / Ceiling and Door & Openings** Ground surfaces Ensure ground surfaces are even, level, and slip-resistant without any abrupt level changes. Floor finishes should be compatible with the robot bases (*e.g. with legs or wheels*) for movements  Fig 3-7 Level and even surfaces with different finishes  Fig 3-8 Avoid any abrupt level changes along pathways Consider covering scupper drains in carpark to allow for deployment of cleaning robots in the carpark instead of using pressure jet spraying which are labour intensive and can cause paints to peel.  Fig 3-9 Covered scupper drain in a carpark facilitates deployment of cleaning robots Walls Design walls to withstand impact in the event of collision with robots Ceilings Design ceilings to withstand the robot's weight and payload where deployment in false ceiling is required Door / Openings Design for doors to withstand impact in the event of collision with robots

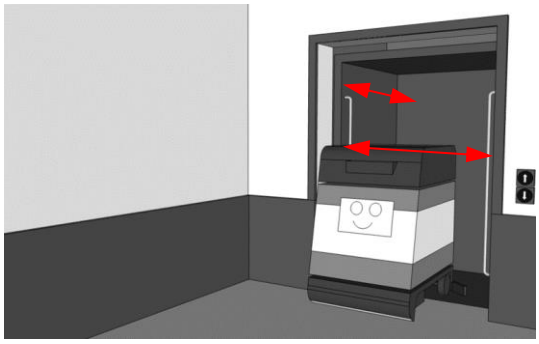
O3.3	Materials & Finishes
O3.32	**Glass and Transparent surfaces** Where full glass surfaces are used in curtain walls or glass railings, increase their detectability by robots such as using glass treated with fritted patterns or opaque safety indicators.  Fig 3-10 An example of fritted glass on curtain walls
O3.33	**Black, Frosted or Reflective Surfaces** Avoid use of black, frosted, or reflective surfaces such as metallic or lacquered surfaces which can cause false negatives to robot's light sensors and lead to collisions.
O3.34	**High-contrast Surfaces** Select contrasting colours and textures on surfaces to improve the robot's perception of objects, especially in an environment with multiple obstacles.
O3.35	**Tactile Paving** Tactile paving on the ground causes excessive vibration and shaking of a robot when traversing over them. Consider tactile paving as a way to physically denote a robot's workspace boundaries or no-go zones.  Fig 3-11 Tactile paving in contrasting colours can be used to physically denote no-go zones such as escalators

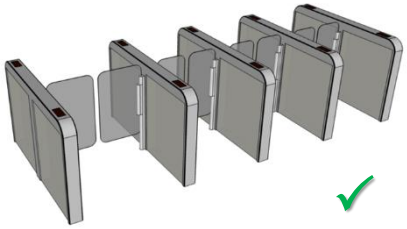
O3.4 Design & Detailing

Objectives:

Design and detailing should (i) help robots detect and avoid obstacles, improving the overall safety for the robots, (ii) ensure provisions for storage and charging, and (iii) consider design features to facilitate robotic manipulation and localisation.

O3.4	Design & detailing
O.3.41	**Storage and Parking Facilities** • Provide storage facilities and space for ease of deployment and retrieval of robots • Designate and provide locations for parking and charging of robots when not in use • For cleaning robots: ▪ Storage rooms for charging of robots should be enclosed and well-ventilated with a washing bay to discharge and top-up water for robots that are not using docking station ▪ Designate and provide water supply and drainage for cleaning robot docking system to achieve self-charging, and self-drain and refill of water ▪ Provide waste disposal equipment for robot maintenance such as clearing of waste collected by sweeping and vacuuming robot • Where there are docking stations and charging points for self-maintenance of robots within the storage rooms, equip rooms with fire detection system. Avoid placing flammable materials (e.g. cleaning consumables such as paper rolls etc.) in the same room.  Fig 3-12 A robot at a docking station, placed next to a wall and along circulation spaces so that it can be easily deployed to serve patrons
O3.42	**Electrical Provision** Provide the necessary electrical provision to facilitate the deployment of robots, such as charging points

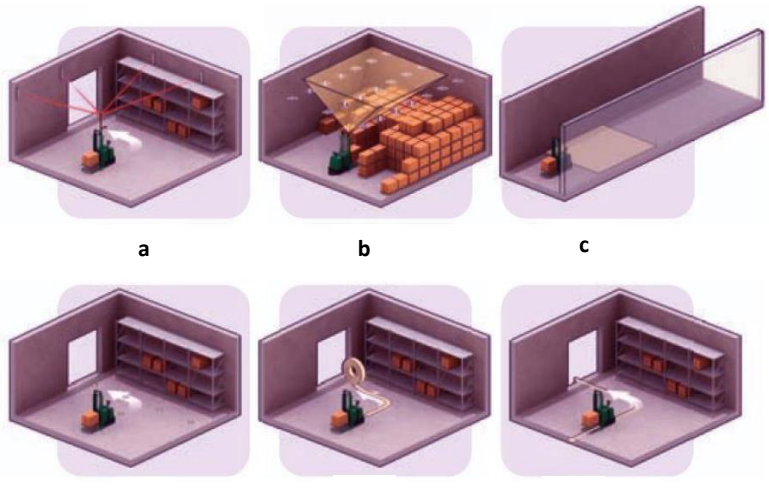
O3.4	Design & detailing
O3.43	**Wall and Furniture Corners** Chamfer or round-off wall corners for safer navigation of robots. Avoid furniture with sharp corners – difficult to detect under poor lighting conditions or robots may have poor edge detection capabilities, to mitigate robot collisions and damage
O.3.44	**Doors** Design doors with required width for robots moving through to facilitate robotic deployment. Consider movement of robots through automated opening of doors, if feasible, and to be synchronised with robot movements when approaching doors.  Fig 3-13 An example of automatic swing door
O3.45	Passenger/Cargo Lifts • Threshold between lift and floor should be as level as possible for robot to enter and exit lift safely. • Reduce gap between lift and floor to a minimum to prevent robot wheels from getting stuck while moving in or out of the lift. • Lift doors and lift cars should be wide enough for robot manoeuvring space while moving in or out of the lifts. • Design maximum lift load to account for robot's weight and its payload and other loads. The robot may have issues coming out of the lift if the total lift load is close to its maximum as the lift may move slightly downwards. • Dynamic display or voice system could be considered to inform people when robot is in the lift. •  Fig 3-14 Width of lift doors and size of lift cars should cater for robots' manoeuvring space while moving in or out of lifts

O3.4	Design & detailing
O3.46	**Security Turnstile Gate** • Design aisle to be wide enough for robot manoeuvring space • Avoid use of frosted, reflective, and mirror-like materials which can cause interference with the robot sensor reading • Avoid use of tripod turnstiles as the turnstile bars are harder to detect with reduced surface area as compared to (preferably opaque) panels found in swing turnstiles  Fig 3-15 Tripod turnstile  Fig 3-16 Swing turnstile
O3.47	**Drains** Avoid discontinuities (*e.g. steep height drop, abrupt sharp turn*) and wall protrusion (*e.g. exposed rebar*) as these inhibit movement for robotic inspection of closed drains.
O3.48	**Landmark features** Incorporate landmark features *(e.g. decorative elements, softscape, etc.)* to break spatial monotony and provide environmental contrast for robots. For information, repetition of similar spatial environments can cause disruptions to the robot's localisation ability. Use visual markers (e.g. QR code printed on floor) to provide additional detection guides for robots' effective operation, such as in scenarios when they return to their charging stations after operation.

O3.5 Technology Integration

Objectives:

Consider technological integration between robots and building infrastructure at planning and design to allow effective and efficient deployment of robots downstream.

O3.5	Technology Integration
O3.51	**Building Infrastructure** Implement fleet management solutions e.g. Robotics Middleware Framework (RMF) to create a communication network system between the robots, IoT devices, and building infrastructure e.g. lifts.
O3.52	**Stable Internet Network** Provide a robust and stable internet network such as 4G/5G technology, repeaters, Wi-Fi API in lifts or other wireless technology in the lift and all common areas (including washrooms) in the building, especially in areas with poor reception to prevent any communication loss. Cybersecurity should be taken into consideration. For more information, please refer to *IMDA IoT Cyber Security Guide*. An internal network within the building specifically for the robot to use could be considered.
O3.53	**Embedded Information Technologies** Integrate information-embedded technologies (QR codes, fiducial markers, RFID tags) within the infrastructure to assist in robot localisation and navigation, where necessary  *Image from Literature Review of Mobile Robots for Manufacturing – Michael Shneider/Roger Bostelman* Fig 3-17 Examples of localisation methods use in Automated Guided Vehicles (AGV) a) laser triangulation, b) ceiling mounted bar codes, c) range or wall-following, d) floor spots/magnets, e) magnetic tape, and f) inductive wire

PART III: MAINTENANCE STRATEGY REPORT

Maintenance Strategy Report

It is important to ensure that all parties understand future maintenance obligations before the building has been constructed. Notwithstanding the recommendations in the Design for Maintainability Guide, designers are advised to prepare a Maintenance Strategy Report at the early stage of the design process to document their maintenance philosophy and operational assumptions.

Report Content

In the Maintenance Strategy Report, designers should state their proposed maintenance strategies which typically include, but not limited to the following:

- unique requirements of the project
- areas requiring maintenance access (including spatial and structural requirements, etc.)
- anticipated maintenance tasks and frequency
- materials / equipment that have specific maintenance requirements
- proposed/ assumed maintenance methodology (equipment, methods, etc.)
- maintenance activities that create specific risks and/or safety issues to maintenance personnel and building users

The report is not intended to be a voluminous paperwork. Information provided in the report should be clear, concise and in a format (e.g. design notes, drawings, tables, charts, and written information - see example below) suitable for parties involved in constructing the building, operating the premises, or carrying out maintenance works.

Consultation with Stakeholders

In developing the Maintenance Strategy Report, designers should consult relevant stakeholders such as building managers, maintenance contractors and end-users who can advise on the safe, appropriate, and cost-effective solutions. The consultative process will ensure that the proposed maintenance methodology is coherent with the future maintenance regime and that all stakeholders are made aware and amenable to the strategy.

Updates and Handing Over

Updates should be made to the report to document the revisions made and eventual maintenance strategies adopted during the design development and construction phases.

Upon construction completion, the Maintenance Strategy Report should be handed to the building owner/ manager and used as a reference for contractors undertaking the maintenance work.

Example

A sample of a proposed maintenance strategy for façade cleaning:

A. EXTERNAL AREAS

	Building Area/ Element	Routine Maintenance	Major Maintenance	Solution		Comments
1	Tower Block - Façade curtain wall • Full height from ground level to roof • All elevations including recesses and protrusions	• Façade cleaning and inspection	• Glass replacement • Curtain wall repairs • Façade lighting repairs	• Routine maintenance • Major maintenance	A	• Permanent suspended platform with monorail system to access all façade surfaces • Integrated restraints in façade system
2	Tower Block – External planters	• Routine inspection and cleaning • Planting, pruning and fertilising	• Plant/ soil replacement • Drainage/ irrigation repairs	• Routine maintenance • Major maintenance	A	• Permanent suspended platform with monorail system to access all planters • Integrated restraints in façade system • Protection rail for hanging planters
4	Tower Block - Entrance glass canopy • Top and underside including structural element	• Cleaning • Luminaire replacement	• Glass replacement • Building services repair (drainage, electrical, etc)	• Routine maintenance • Major maintenance	B	• Access using self-propelled access platform • Accessible via paved fire engine access • Fall arrest system provided on surface of canopy
5	Covered walkways	• Cleaning	• Cladding repairs • Building services repair (drainage, electrical, etc)	• Routine maintenance • Major maintenance	C	• Accessible via ground level walkway • Fall arrest system provided on surface of canopies

B. INTERNAL AREAS

	Building Area/ Element	Routine Maintenance	Major Maintenance	Solution		Comments
6	Atrium	• Glass cleaning • Cleaning shading devices • Luminaire replacement	• Glass repair/ replacement • Ceiling/ shading devices repair • Building services repair	• Routine maintenance • Major maintenance	D	• Personnel lifting hoists for suspended platforms

Legend

Solution A –Suspended platform with monorail system (see details in Annex 1)

Solution B – Self-propelled access platform (see details in Annex 2)

Solution C – Rope access (see details in Annex 3)

Solution D – Personnel lifting hoists (see details in Annex 4)

References

Source	References
BCA	Approved Document
	BIM Guide for Asset Information Delivery
	Code on Accessibility in the Built Environment
	Façade Access Design Guide
	Guide to Smart FM
LTA	Architectural Design Criteria
	Architectural Materials and Workmanship Specifications
	Civil Design Criteria
	Code of Practice on Street Works Proposals Relating to Development Works
	Materials and Workmanship Specifications
	Standard Details of Road Elements
MHA	Guidelines for Enhancing Building Security in Singapore
MOM	WSH (Design for Safety) Regulations
NEA	Code of Practice on Environmental Health
NParks	Guidelines on Greenery Provision and Tree Conservation for Developments
	Landscape Design Guidelines for Productive Maintenance
NParks (CUGE)	Guidelines on Design for Safety of Skyrise Greenery
	Selecting Resistant Species and Varieties for the Control of Pests and Diseases
	Sustainable Landscape
PUB	Code of Practice on Sewerage and Sanitary Works
	Code of Practice on Surface Water Drainage

Source	References for Codes and Standards for access systems
British Standards	BS EN 795 Personal fall protection equipment – Anchor devices BS EN 1808 Safety requirements for suspended access equipment BS 6037-1 Code of practice for the planning, design, installation, and use of permanently installed access equipment – Suspended Access Equipment BS 6037-2 Code of practice for the planning, design, installation, and use of permanently installed access equipment – Travelling ladders and gantries
Enterprise Singapore	SS 528 Specification for Personal fall-arrest systems SS 607 Specification for design of active fall-protection systems SS 588-1 Personal equipment for protection against falls – Rope access systems – Part 1 SS 588-2 Personal equipment for protection against falls – Rope access systems – Part 2 SS 598 Code of practice for suspended scaffolds SS 616 Code of practice for safe use of mobile elevating work platforms SS 617 Code of practice for the lifting of persons in work platforms suspended from cranes SS 642 Code of practice for pneumatic waste conveyance system TR 69-1 Video analytics within video surveillance systems – Part 1: Reference architecture and interoperability TR69-2 Video analytics within video surveillance systems – Part 2: Section, installation, and benchmarking TR 93 Data Exchange between robots, lifts, and automated doorways to enable autonomous operations

Acknowledgements

The Design for Maintainability Guide was prepared by the Integrated Planning & Design - Design for Maintainability (IPD-DfM) Taskforce, which comprised representatives from the following organisations:

I. Public Sector agencies

- Building and Construction Authority (Co-chair)
- Housing & Development Board (Co-chair)
- JTC Corporation
- Ministry of Home Affairs
- National Environment Agency
- National Parks Board

II. Industry stakeholders

- Association of Consulting Engineers Singapore
- Bintai Kindenko Pte Ltd
- CapitaLand Ltd
- CES Salcon Pte Ltd
- C&W Services, Singapore
- International Facility Management Association, Singapore Chapter
- Institution of Engineers, Singapore
- Jardine Engineering Corporation Ltd
- Johnson Controls
- Keppel Land Ltd
- MOH Holdings Pte Ltd
- Singapore Institute of Architects
- Starklit Consultancy
- Surbana Jurong Pte Ltd

III. We would also like to thank the Singapore University of Technology and Design (SUTD) for being instrumental in co-developing the Robotics & Automation Chapter.

IV. Our sincere appreciation to the following organisations for their inputs:

- CBM Pte Ltd (Robotics & Automation Chapter)
- Gaussian Robotics Pte Ltd (Robotics & Automation Chapter)
- Infocomm Media Development Authority (Robotics & Automation Chapter)
- ISS M&E Pte Ltd (Robotics & Automation Chapter)
- KONE Singapore (Robotics & Automation Chapter)
- LionsBot International Pte Ltd (Robotics & Automation Chapter)
- Landscape Industry Association of Singapore (Landscape Chapter)
- Singapore Institute of Landscape Architects (Landscape Chapter)
- Singapore Pest Management Association (Environmental Services considerations)