GUIDE TO SMART FM

An initiative from the FMIC (Facilities Management Implementation Committee) Smart FM Taskforce

Guide to Smart FM Revision Log

S/N	Brief description of changes	Revision date
01	First issue	1 Oct 2019
02	Second issue	6 Sep 2022
02.1	Second issue with updates: - Updated Preface - Added Smart Energy Management Committee and contributors to the case study writeups under Acknowledgement - Updated Section 4.2.4 on Cybersecurity for Smart Buildings - New case study under Appendix C.6 Smart Energy Management for ACMV Systems - New Appendix F on Essential Smart FM use cases	7 Oct 2024

Preface

With our ageing workforce and building stock, there is a need to transform our FM industry to shift from the current ways of managing building facilities that are labour intensive, to a productive one, using smart solutions, predictive maintenance, and data analytics. BCA was tasked to coordinate the development of the FM industry as part of the Real Estate Industry Transformation Map (ITM) launched in February 2018. A tripartite Facilities Management Implementation Committee (FMIC) was formed in April 2018, comprising both public and private building owners, FM service and solution providers, trade associations and chambers (TACs), and unions, to spearhead and develop detailed action plans to implement the transformation strategies identified in the Real Estate ITM.

An Integrated Smart FM Taskforce under the FMIC was formed to help drive industry adoption of technology and leverage on smart FM technology solutions, to streamline existing FM work processes and enhance FM productivity and service quality. This ***Guide to Smart FM*** was developed by the Taskforce and launched on 1 October 2019 to provide Building Owners and FM Managers with an easy-to-use reference, to guide them on the key steps to take in their Smart FM journey.

Since then, there has been greater awareness and adoption of Smart FM solutions, especially Type 1 and 2 Smart FM solutions such as workflow automation and system optimization. Going forward, as we make further progress towards Integrated FM and Aggregated FM (IFM and AFM), the Taskforce seeks to provide more guidance as we start to adopt more advance Type 3 Smart FM technologies. FM processes and digital skillset of our workforce would also need to be reviewed and enhanced. These new topics would be covered in Chapters 3, 4, and 5.

In Chapter 3, the concept of Digitalisation Maturity Map is proposed to map out the different levels and systems of digital adoption and integration across the FM value chain. When there is clarity and digital integration between vendors/sub-contractors, FM Companies, and Building Owners, we stand a better chance to unlock the potential of digital transformation and harness the synergy within and across the FM supply chain for performance optimisation.

To support these new processes, best practices in data management such as Common Data Environment (CDE) for FM, data connectivity and interoperability are discussed in Chapter 4. In Chapter 5, a list of digital skillsets to support Type 3 Smart FM processes and technologies are mapped out. These skillsets are aligned and mapped with the Technical Skills and Competencies (TSCs) under the BE Skills Framework (SFw).

More case studies have also been included in Appendix C to demonstrate the various Smart FM use cases at CapitaLand and Yale-NUS College. The guide also added specific use cases on predictive maintenance that were developed and tested by the solution providers, such as Lingjack on Smart Fire Safety & Emergency and Schindler Ahead on Lift Remote Monitoring & Diagnostics. It also features Azendian's Estate HVAC Energy Optimisation solution, which is a data-driven smart energy management solution.

Apart from productivity improvements, FM transformation also has significant contribution towards meeting our sustainability goals under the Singapore Green Plan 2030. In many cases, Smart FM solutions for predictive maintenance can also help building operators in energy and resource optimisation simultaneously. Upfront considerations on design for maintainability would ensure that the building infrastructure can be adequately maintained for optimum performance across its life cycle. To encourage adoption of such good practices, we have incorporated Smart FM solutions into the Maintainability and Intelligence sections of the latest GM 2021 revision. In addition, policy measures were also introduced under the GreenGov.SG for all public sector projects to achieve the GM2021 Maintainability Badge. To incentivise private sector adoption, we have also introduced the BE Transformation GFA incentive. This Guide is updated to complement these efforts.

Extensive consultations were held with various public agencies, building owners, FM service and solution providers to understand their challenges, plans, and valuable lessons learnt from their experience in implementing Smart FM, integrating, and aggregating FM services. With this enhanced Guide, the FMIC and Taskforce hope to encourage the industry to shift towards stronger partnerships between service buyers and providers to collaboratively achieve greater synergistic outcomes and economies of scale.

Acknowledgement

This ***Guide to Smart FM*** was developed with inputs from the Integrated Smart FM Taskforce. Special thanks is given to all Taskforce members and resource persons for their significant contribution and support.

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Chapter 1. Introduction

Smart FM refers to the integration of systems, processes, technologies, and personnel to enhance the management of a building's facilities. It is a mean to an end and thus, should not begin with *technology* in mind. It is important to consider the *process* and *people* aspects too to harness the full potential of Smart FM and achieve a holistic solution that can support data-driven decisions, create change and improve outcomes (see *Figure 1*).

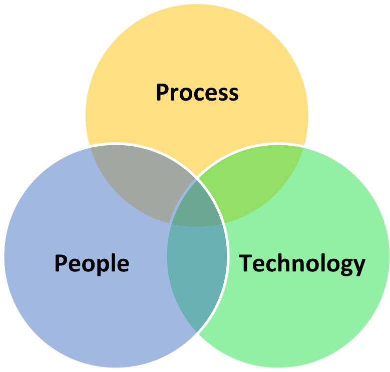

Figure 1. Transformational change through smart FM requires more than just technology

In recent years, accelerated by the COVID-19 pandemic, there has been a broader interest from Building Owners to develop smart buildings, estates and/or districts that to meet or exceed sustainability, health, and safety requirements, in addition to enhancing the customers' experiences. Beyond ***automating business and FM processes*** and ***enabling a higher level of smart control and management***[1] for Building Owners and FM Managers, it is also about ***creating connected and interactive smart usable spaces*** for the tenants, residents and visitors to a building, coupled with a ***seamless end-to-end user experience***.

With the rise of technologies such as Artificial Intelligence (AI), Internet of Things (IoT) devices, Immersive Media (AR/VR), and cloud-based technologies, the FM industry is now able to leverage such technologies to help Building Owners achieve the above mentioned, transform their business model, and gain a competitive edge in the market.

[1] For example, command-and-control for security and resource deployment, on-demand energy management, use of digital twins for simulation and modelling, use of data analytics and machine learning to identify inefficiencies in building systems for optimisation, etc.

To Foster Stronger Partnerships and Enable Seamless FM Processes and Service Delivery, through Purposeful Integration and Aggregation

Building Owners, Facility Management Companies (FMCs) and Service/ Solution Providers are encouraged to forge stronger partnerships to enable seamless FM processes and service delivery through purposeful integration and aggregation, where:

- Integration refers to bundling of two or more inter-disciplinary services (e.g., Cleaning, Security, M&E, etc) together; and
- Aggregation refers to consolidating demand and resources, such as across a portfolio of buildings or at a district level.

Integration is not equivalent to single sourcing, multi-tasking nor a loose consortium of companies to bid for a project. A truly integrated FM model delivers the full spectrum of FM services, coordinated via a single platform. Integration can occur at 3 different junctures in this model:

1. At the point of service delivery with multi-functional robots or multi-skilled personnel;
2. At the point of response where subsystems are linked to complement each other, e.g., robot integration with lift;
3. At the command level, with workforce management tools that give FMC visibility into its service personnel, equipment, and workflow to enable optimal deployment and outcome reporting

Such integration and aggregation can be carried out at the demand side, i.e. Building Owners with a portfolio of buildings, to facilitate a better overview and management of resources; and/or supply side, where the FMCs and Service/ Solution Providers manage several FM contracts as a pool.

Integration and aggregation should be seen as two sides of the same Smart FM coin and is intrinsic to the delivery of outcome-based contracts. They give the FMCs the latitude to fully exploit their competitive edge and manage their FM resources optimally while meeting the discerning needs of each Building Owner.

Considering the ***process***, ***technology*** and ***people*** aspects mentioned earlier to harness the full potential of Smart FM:

Process: With increased adoption of integrated FM contracts that are outcome-based, the business model between Building Owners, FMCs, and Service/Solution Providers will evolve to become a strong and sustainable co-operative partnership that can bring about favourable outcomes for all parties. Coupled with an assurance of a longer contracting period, the FMCs and Service/Solution Providers will see greater value in investing and leveraging on technology to support its workforce.

Technology: As a mean to an end, a deliberate review should be carried out to ensure that the implementation of proposed Smart FM technology solutions is well aligned and integrated with the Building Owner's business requirements and existing FM processes to achieve the desired operational outcomes. When deployed and replicated or scaled up appropriately, these solutions can facilitate purposeful integration and aggregation by automating and monitoring the performance of multiple buildings across a portfolio or district and analysing such data centrally to support data-driven decisions on predictive and prescriptive maintenance. This can optimise and transform the delivery of a FM operation or process and unlock synergies across various FM disciplines.

People: Building Owners, FMCs, and Service/Solution Providers should plan for regular training of their FM workforce to enable them to be aptly or deeply skilled for more effective application of the Smart FM technology solutions. The adoption of outcome-based contracting also allows for the upskilling and cross-training of the workforce to expand their existing roles and be multi-skilled. Besides creating new, higher value-added jobs within the organisation, this also strengthens the adaptability and agility of the workforce to be deployed across various FM disciplines and/or facilities.

With the above in mind, transformational change through integration and aggregation, enabled by technology adoption, can translate into economies of scale with improved operational or process efficiency, optimised manpower and resource deployment, as well as enhanced manpower productivity.

Building Owners and their FM Managers can evaluate the outcome and/or contracting efficiency by collating occupants' feedback, reporting energy savings or usage, tracking the time to resolve incidents, etc. This in turn allows the Building Owners and FM Managers to determine how well the Smart FM solutions have been implemented, used and managed, thereby streamlining and transforming the way existing FM processes and practices are carried out.

5-Step SMART Process to Smart FM

A 5-step SMART process, shown in *Figure 2* below, is recommended to aid the Building Owners and FM Managers in their Smart FM journey. The detailed steps will be further explained in ***Chapter 2. The 5-step SMART Process***.

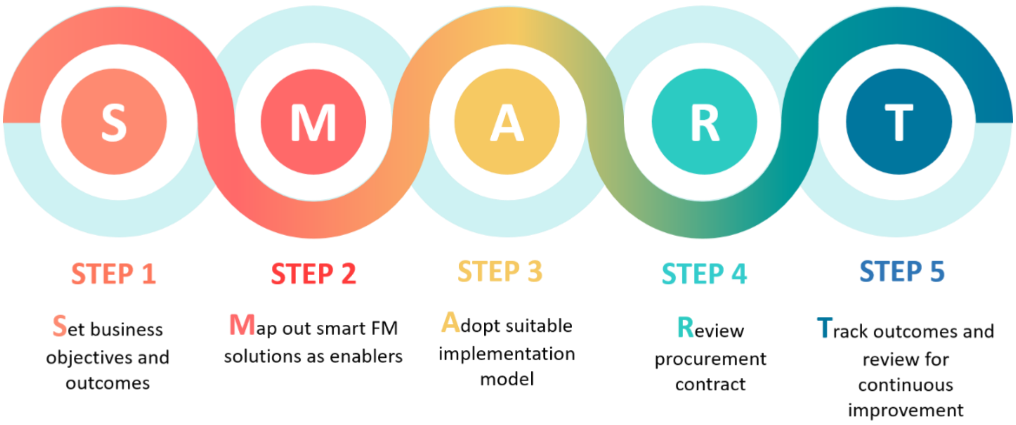

Figure 2. 5-Step SMART process to Smart FM

Chapter 2. The 5-step SMART Process

Step 1: Set Business Objectives and Outcomes

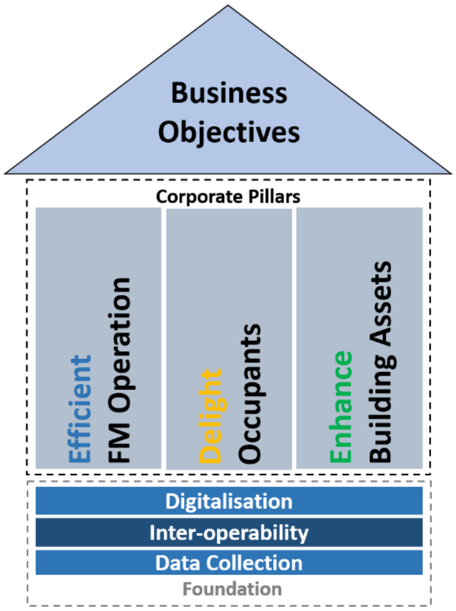

Figure 3. Fundamentals of Smart FM implementation

Technological innovation can shape and impact FM practices, but there is a need to evaluate and align its business objectives with its fundamental principles of integrating people, place, process, and technology.

The principles shown in Figure 3 are reinforced by the following corporate pillars in the implementation of Smart FM:

- Delivering efficient FM operations
- Ensuring satisfaction of the occupants (e.g. employees, tenants, etc.)
- Enhancing building assets through upgrading works or proper maintenance

Building Owners and FM Managers can refer to these principles to identify their key business objectives. This will ensure that Smart FM is planned for from the inception of a building or estate design which is critical to its successful implementation.

Setting Business Objectives, Desired FM Outcomes and Corresponding Key Performance Indicators (KPIs)

The adoption of Smart FM technologies should primarily be driven by an organisation's business objectives. Building Owners and FM Managers are recommended to first identify their top 3 business objectives with the Smart FM fundamentals in mind.

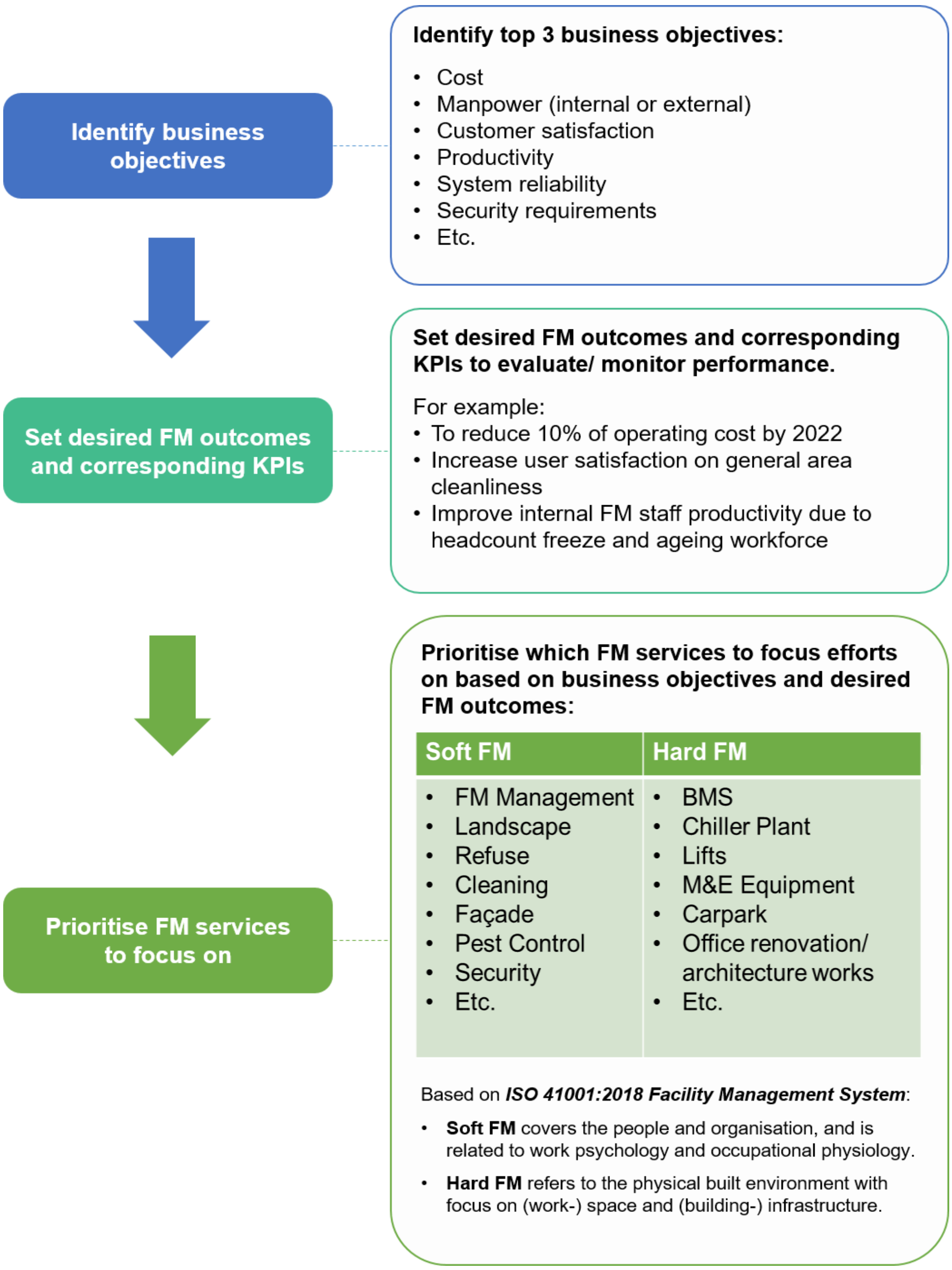

Figure 4. Flowchart on Step 1 of the 5-Step SMART process

The desired FM outcomes can be established based on these identified business objectives and pertinent operational issues that need to be addressed. It is recommended for Building Owners and FM Managers to determine corresponding KPIs to evaluate and monitor the performance of each desired FM outcome.

Lastly, Building Owners and FM Managers are to decide which FM services to focus on. The FM services should be prioritised based on their impact in realising the desired FM outcomes and KPIs. The template in *Table 1* can help to facilitate this process.

Top 3 Business Objectives	Check Point	Desired FM Outcomes and Corresponding KPIs	High-Priority FM Services
E.g. Cost	*E.g. What is my annual FM expenditure and cost breakdown? Which area can be improved/reduced?*	*E.g. To reduce energy cost by 10% by 2022*	*E.g. Chiller plant maintenance*
E.g. Customer satisfaction	*E.g. What is my customer satisfaction level for each services?*	*E.g. Increase user satisfaction on general area cleanliness and reduce complaints by 20%*	*E.g. Cleaning of toilets (high volume of user feedback)*
E.g. Productivity	*E.g. Does the task or project required high amount of manual processes or paperwork? Which area can be improved further?*	*E.g. Increase internal FM staff productivity due to headcount freeze and ageing workforce Increase productivity by 15%*	*E.g. FM management processes (manpower intensive)*

Table 1. Template to rank business objectives, set desired FM outcomes, and determine high-priority FM services to focus on

What Should Building Owners and FM Managers Consider in Step 1:

- What are my top 3 business objectives?
- What do I want to achieve and set as my desired FM outcomes, based on my business objectives and issues faced?
- What corresponding KPIs can I set to monitor the progress of my desired FM outcomes?
- Which FM services should I prioritise to address the desired FM outcomes?
- Can I streamline my current FM processes and procurement framework to meet the identified business objectives and desired FM outcomes?

Tool to use

Table 1: Template to rank business objectives, set desired FM outcomes, and determine high-priority FM services to focus on

Step 2: Map Out Smart FM Solutions as Enablers

The next step is for Building Owners and FM Managers to determine suitable technology solutions for the high-priority FM services identified in Step 1. At this stage, it is important for Building Owners and FM Managers to concurrently review and streamline current FM processes and explore how Smart FM technologies can be integrated.

Building Owners and FM Managers can refer to ***Appendix A: List of Smart FM Point Solutions*** for solutions that addresses specific FM pain points related to infrastructure and common services.

The Singapore International Facility Management Association (SIFMA) has also collaborated with the Agency for Science, Technology and Research (A*STAR) to develop a Consortium Operation and Technology Roadmap (COTR) in 2019 for the FM sector (see ***Appendix B: Facilities Management Consortium Operation and Technology Roadmap (COTR)***). The COTR aims to outline the general trends (e.g., push and pull drivers towards Smart FM) and direction of the FM sector, and maps out Smart FM solutions that are deemed relevant for the sector from short to long term.

Establish a Smart FM Framework

Building Owners and FM Managers can take reference to the abovementioned to identify technology solutions they can map into the Smart FM Framework as shown in Table 2. The Framework serves to facilitate dialogues between Building Owners and Service/Solution Providers. Proposals can be reviewed alongside the Framework to see how the technology solutions offered can help to achieve the desired FM outcomes.

The Framework also classifies Smart FM solutions into three types of "smartness" where Building Owners and FM Managers can assess the scope and type of solutions each FM service requires. It is important to note that the three types of "smartness" are not in any order of merit or maturity of technologies. The choice of solutions should be determined by a cost-benefit analysis in achieving the desired Smart FM outcomes.

Type/ Scope	Description	Building Level FM Services				Towards Aggregation	Clustering
		Energy	Security	M&E Functions	Environmental Services		Smart FM implementation across:
Type 1 Digitalised Workflow Automation	When triggered, by an incident, automatically initiates a process that track, log, and close the incident		Workflow Automation System			Towards Aggregation	Mixed Developments
		EPC Remote Monitor BCA Portal	Video Monitoring with Incident Detection	Lift Monitoring	Toilet Sensors, Compactor		
Type 2 Optimisation within System	Use data analytics to - Optimize systems - Quantify FM efficiency - Perform Preventive/ Predictive maintenance	Connected Services for Chiller Optimization	Security Kiosk and Occupants Engagement	Failure Prediction	Usage and Feedback data to optimize cleaning		Portfolio of Buildings
			Connected Lighting Systems, with temperature/RH and occupancy sensor		Rodent Surveillance		
Type 3 Integration Across Systems	Optimize resource deployment and utilisation across many systems	Co-sharing or Hot Desk Integrating Booking, Billing, Security, Space Management, Thermal Comfort		Integration of systems for Demand/Occupant-based building control & optimisation			District Level

Table 2. Example of a Smart FM Framework with multiple solutions identified

Other than looking into adoption of solutions to enhance business operations and productivities, Building Owners and FM managers should also consider how data can be collected, managed, and analysed for innovation. For example, data collected from people-traffic information could help business owners identify the right timing to push out attractive store promotion via the mall's customer app or being able to allocate the right amount of manpower required for cleaning services during peak and non-peak season so as to ensure that the public or workspaces are well maintained. Such approaches can bring greater value-add not only for Building Owners but also for the tenants and employees.

Explore Aggregation Opportunities

Building Owners and FM Managers can explore areas where economies of scale can be achieved through aggregation at all 3 types of "smartness" (e.g., Type 1, 2 and/or 3). For Building Owners with a portfolio of buildings, the aggregation may be done at their end (e.g., demand side). For example, a technology solution can be deployed, or certain FM functions like security and cleaning can be aggregated, across the portfolio of buildings, for a better overview and management of resources.

Building Owners with a single development may explore aggregation at the supply side, through FMCs and Service/Solution Providers. When more Building Owners move from traditional prescriptive-based contracting to outcome-based, FMCs and

Services/Solution Providers can better manage their resources to meet services demands. Greater benefits can be reaped through aggregation for buildings in a vicinity or district that adopt outcome-based contracting. This will be covered and explained further in Step 4.

<u>What Should Building Owners and FM Managers Consider in Step 2:</u>

- What type of "smartness" (Type 1, Type 2, or Type 3) is each high-priority FM service currently at?
- What type of "smartness" do I want to achieve for each high-priority FM service? Is it aligned with my business objectives and desired FM outcomes?
- What are my pain points and gain points for each high-priority FM service?
- Do the technology solutions proposed by the FMCs and Service/ Solution Providers fit the requirements to achieve my desired FM outcomes?
- How would I like to engage the building occupants and visitors?
- Are there FM services that could be integrated to provide multi-functional and enhanced outcomes, e.g. connected lighting systems?
- Are there areas where aggregation can be done to achieve economies of scale – at demand and/or supply side?
- Is it advantageous to aggregate demand across a portfolio of buildings?

<u>Tool to use</u>

Table 2: Smart FM Framework

<u>References</u>

- ***Appendix A: List of Smart FM Point Solutions***
- ***Appendix B: Facilities Management Consortium Operation & Technology Roadmap (COTR)***

Step 3: Adopt Suitable Implementation Model

Upon deciding which Smart FM solutions to adopt under Step 2, it is important for Building Owners and FM Managers to determine how these solutions can be implemented.

Where relevant, Building Owners and FM Managers can consider incorporating the concept of Services 4.0[2], which envision services to be end-to-end, frictionless, empathic, and being able to anticipate customer needs using emerging technologies. In Services 4.0, businesses will need to meet changing customer needs quickly, innovate, scale and be able to create new value in order to differentiate themselves from competitors.

Model A: Integrated Smart FM Solution

The following implementation model (*see Figure 5* below) is one in which the smart solutions feed data into an integrated software suite, either provided by the appointed FMC or acquired by the Building Owner to operate and manage its FM operations.

The first approach is resource-lite and allows the Building Owner and FM Manager to have a reasonably comprehensive management dashboard. While the latter requires considerable scale and resource commitment to develop a reasonably comprehensive system and management dashboard, it allows customisation based on the organisation needs and is beneficial for Building Owners with a big portfolio of buildings. Regardless of which approach, both should provide the Building Owner the autonomy of its operation.

[2] Services 4.0 is Singapore's response to the Services and Digital Economy (SDE) Technology Roadmap, envisioning Singapore delivering next-generation services that are end-to-end, frictionless, empathic, and anticipatory to customer needs. (Reference: https://www2.imda.gov.sg/infocomm-media-landscape/services-40)

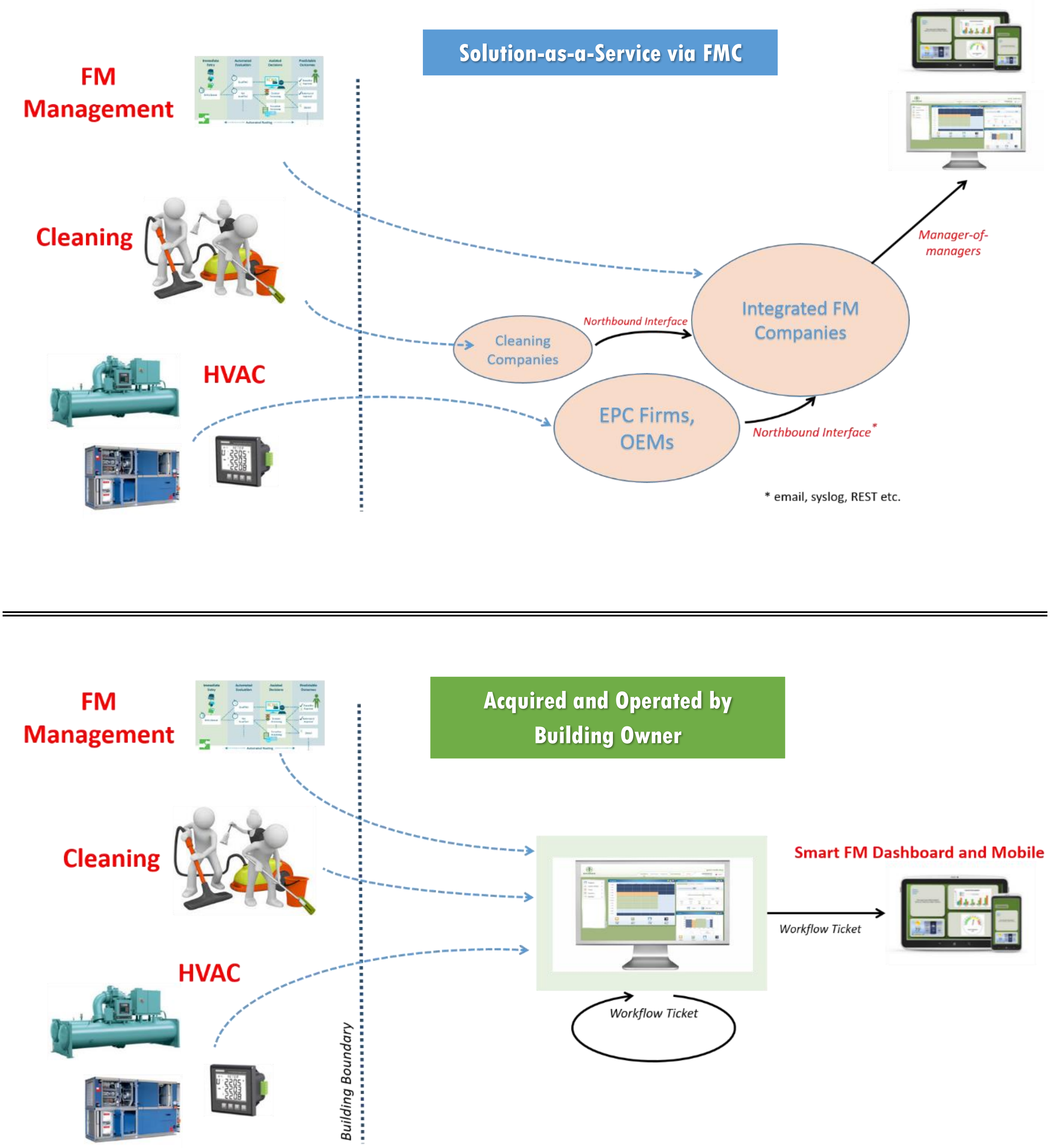

Figure 5. Model A: Integrated Smart FM Solution

The use cases of this model include JTC Corporation's J-Ops and the CapitaLand Integrated Building Platform (IBP) (Refer to ***Appendix C: Case Studies***).

Model B: Single Smart FM Solution

This second implementation model is one in which Building Owners procure specific Smart FM services and solutions individually and manage them with the software tools provided by each individual Service/Solution Provider.

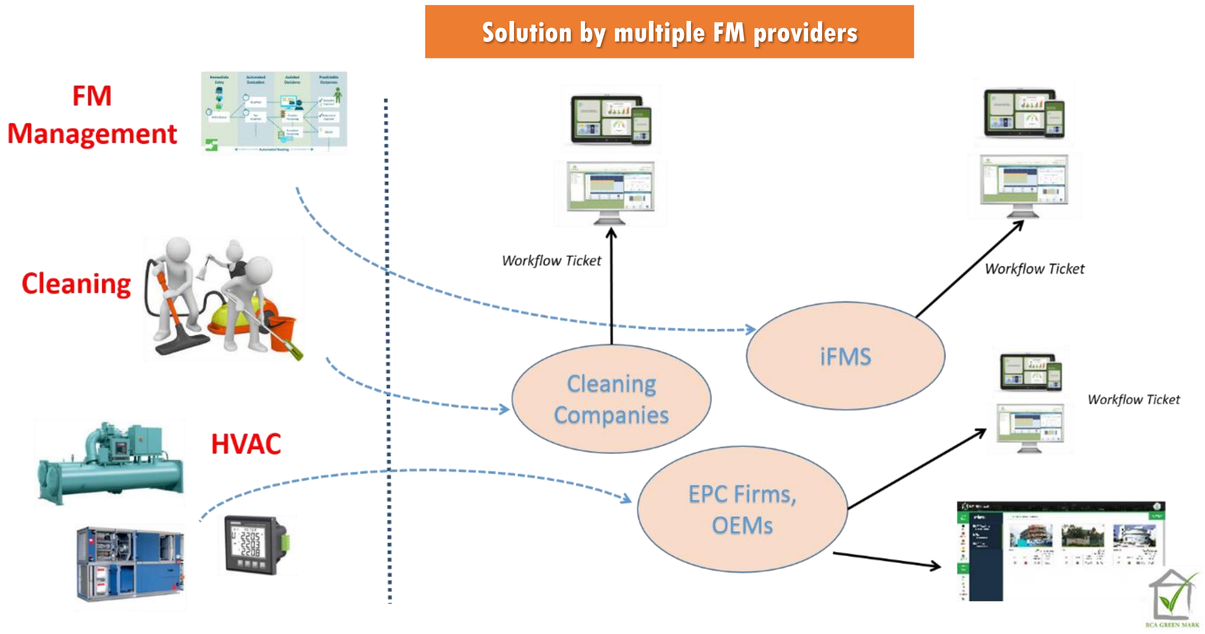

Figure 6. Single Smart FM Solution

It has become more common for specialised FM suppliers to develop smart solutions to complement their products and services for remote monitoring, fault detection, diagnostics and optimisation. For example, major chiller suppliers have deep expertise and extensive performance data of their equipment. The leading suppliers have developed smart IoT solutions (connected services) for remote chiller plant monitoring and predictive maintenance.

While this approach can leverage on the specialised expertise and data of the Service/Solution Providers, Building Owners and FM managers should keep in mind that if integration of multiple systems or solutions is within the future pipeline, the adopted or developed solutions should have open Application Programming Interfaces

(APIs) to allow integration with a horizontal platform for central command-and-control and data exchange, as seen in Model A.

Additional Considerations

It should be emphasised that none of the implementation models are superior to another. The decision on the type of model to adopt must be based on the Building Owner's business objectives, operational priorities and desired FM outcomes.

A phased adoption, variation or hybrid of the implementation models is entirely possible. For instance, a Building Owner with a large portfolio of buildings may start with a centralised FM operations centre (i.e. Model A) and have been reaping the benefits and cost savings from rectifying poorly commissioned equipment and sensors that have "drifted" in accuracy (low-hanging fruits). To attain the next leap of optimisation, the Building Owner may see it advantageous to subscribe to a chiller vendor's remote monitoring service (i.e. Model B). This is with consideration that the chiller vendor has proprietary knowledge of its chillers and the possibility to leverage on its collective insights obtained from monitoring its global installed base.

As Building Owners and FM managers start to enjoy the benefits that can be gained from leveraging large data sets, such as optimising business processes or accelerating the development of artificial intelligence (AI), there are also concerns over trust and security thereby hindering the mass sharing of this information. Data sharing is a multi-disciplinary process which involves not only enabling technology, but also business and legal considerations. In June 2019, the Info-communications Media Development Authority (IMDA) and Personal Data Protection Commission (PDPC) have announced the first comprehensive Trusted Data Sharing Framework[3] with the aim to guide organisations through the data sharing journey. Building Owners may refer to it for key considerations to take into account when planning data partnerships.

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[3] "*Enabling Data-Driven Innovation Through Trusted Data Sharing In A Digital Economy*", 28 June 2019, https://www2.imda.gov.sg/news-and-events/Media-Room/Media-Releases/2019/Enabling-Data-Driven-Innovation-Through-Trusted-Data-Sharing-In-A-Digital-Economy

System and Technical Requirements

The implementation model selected in this Step determines the working arrangement with the FMCs and Service/Solution Providers. This will impact the Building Owner and FM Manager's ownership (e.g., cloud-hosted or on-premises) and the degree of freedom and access to the integrated FM system (iFMS) and/or individual FM sub-systems.

System and technical requirements in relation to these should be specified in the procurement contracts. The specification should include the data and format to be fed to the iFMS of the building, as well as the "north-bound" data interface to which the FM sub-systems can lodge incidents with the iFMS, for the purpose of logging, dispatch and management.

Besides data fields like data and time of incident and resolution, severity and classification, other information required to enable outcome-based KPIs to be objectively computed or measured should be detailed as well. For example, number of incidents per week, mean time to failure, energy efficiency index, energy savings, financial savings, turnaround time or time to resolution.

Specifications within the procurement contracts are important to ensure that the Smart FM solutions and systems are properly put in place to support and contribute to the Smart FM platform. This would reduce operational disruptions and any cost implications to redesign the Smart FM infrastructure within the building.

What Should Building Owners and FM Managers Consider in Step 3:

- What is my current working model for existing FM processes and services?
- How would I like to work with my FMCs or Service/Solution Providers?
- Which implementation model is more viable at this point to incorporate the various technology solutions identified in Step 2? Or would phased adoption or a variation or hybrid of the implementation models be more applicable?
- Does the selected implementation model meet my business objectives, operational priorities and desired FM outcomes?
- How to ensure that I own all the data, regardless of the type of implementation models selected?
- Are the system and/or technical requirements specified within my procurement contracts adequate?

References

- IMDA and PDPC's Trusted Data Sharing Framework *(https://www2.imda.gov.sg/news-and-events/Media-Room/Media-Releases/2019/Enabling-Data-Driven-Innovation-Through-Trusted-Data-Sharing-In-A-Digital-Economy)*

Step 4: Review Procurement Contract

After the Building Owners and FM Managers have identified the appropriate implementation models and related system and technical requirements in Step 3, they can proceed to work out the procurement contracts with the FMCs and Service/Solution Providers.

With the increasing number of data-driven smart technology solutions in the market, there is a shift from traditional headcount-based to outcome-based procurement methods. This shift has allowed innovative solutions that are less-resource intensive to enter the market[4]. At the same time, this has encouraged FMCs and Service/Solution Providers to improve their operations to meet the Building Owners' expectations[5].

Longer Contract Terms

When outcome-based measurements become the primary focus of the procurement contracts, both Building Owners and the FMCs or Service/Solution Providers can achieve more value as working partners, sharing a common interest towards a successful business and performance relationship[6]. With the assurance of a longer contracting period, service and solution providers may be more willing to leverage on technology as enablers to supplement and complement its workforce to achieve better and more insightful outcomes over existing procurement methods, resulting in a win-win for all parties.

Employees of FMCs and Service and Solution Providers can be given the opportunity to upskill and benefit from job redesign to take up more complex roles resulting in greater productivity as well as increase in wages.

It is recommended that Building Owners and FM Managers should specify a contract duration of at least three years, with another three years extension. In some public

[4] Ministry of Home Affairs, *Guide on outcome-based security contracts*
[5] National Environment Agency, *Guide on specification for outcome-based cleaning contracts*
[6] Interllect's Outcome-Based Agreement Group, *A guide to outcome-based agreements – a better way to do business*

agencies that have successfully adopted Smart FM, their contract duration ranges between five to ten years.

A longer contract term can incentivise the FMCs or Service/Solution Providers to invest in technology solutions, and upgrade the supporting infrastructure of the buildings to be ready for Smart FM.

Define Outcome-based Measurements

Each class of stakeholder will have different expectations, requirements, and desired outcomes.

When Building Owners and FM Managers work out the procurement contracts with the FMCs and Service/Solution Providers, it is also important to identify and understand the requirements of various stakeholders. The technical specifications within the contract will need to take these into consideration:

a) **Financial stakeholders** will desire information on how the Smart FM implementation will impact the company's financial metrics and bottom line, as well as the interfacing to its accounting system.

b) **Operational stakeholders** that keep the building functioning on a day-to-day basis will be concerned with occupant satisfaction, ease of operation, access to critical systems' information, and productivity of the maintenance staff. They will also want access to all the building's systems to have better situational awareness, and address issues in real time, where required.

c) **Sustainability stakeholders** will be concerned with energy and water efficiency, utility optimisation, and how to reduce carbon emissions and save resources.

d) **Productivity stakeholders** will be concerned with occupant and user comfort, and will want to know about utilisation of the building's spaces and how systems integration can improve the productivity of workflow processes and user experience.

e) **Security stakeholders** may look beyond surveillance and want the building's intelligence to maintain a proper access control system, help disseminate messages and locate people during an emergency.

f) **Public communications stakeholders** will want to include performance data in lobby displays to promote various initiatives deployed within the building (e.g., sustainability efforts) and help visitors with registration and wayfinding.

All the parties mentioned above will be interested in obtaining detailed data in their specific areas so that they can analyse the data gathered and optimise relevant building systems according to best practices. Defining metrics and outcome-based KPIs for tracking, i.e. outcome-based measurements, will help to clarify the data flow, technical requirements and reporting or data visualisation to fulfil their respective work scope.

Building Owners and FM Managers can refer to guides listed in [2], [3] and [4] of ***References*** that will provide details on specifying operational requirements aligned with an outcome-based procurement approach for energy performance contracting, security and cleaning services.

<u>Integrated Facilities Management (IFM) Contract</u>

Building Owners and FM Managers can explore areas where greater economies of scale can be achieved by aggregating their demand within a building and/or across a portfolio of buildings through an IFM contract. IFM, together with a longer outcome-based contract term, will allow FMCs and Service/Solution Providers greater payback certainty and flexibility to explore innovative Smart FM solutions (e.g., IoT, integrated command centre, digital twin modelling, interoperability of FM solutions) that enable on-demand and more optimal deployment of resources to meet the desired outcomes. Such integration of manpower, technology and processes enables FM service delivery to be optimised, leading to better service, at lower costs in the longer term.

What Should Building Owners and FM Managers Consider in Step 4:

- What are the outcome-based measurement, incentives and penalty for each FMC or Service/Solution Provider?
- Can I work together with the FMCs or Service/ Solution Providers to adopt a longer contract term?
- Can the FMCs or Service/Solution Providers optimise delivery of their services and solutions if I aggregate demand across my portfolio of buildings?
- What system or technical requirements should I take note of and incorporate within the procurement contract?
- Have my technical specifications for the Smart FM solutions taken into consideration the various stakeholders' requirements?
- Can I aggregate demand within a building and/or across my portfolio of buildings through an Integrated FM contract?

Step 5: Track Outcomes and Review for Continuous Improvement

After the procurement and implementation of the Smart FM solutions, it is essential for the Building Owners and FM Managers to monitor and review the Smart FM solutions adopted for continual improvement. It is also recommended that they re-examine Steps 1 to 4 to explore areas for further improvement.

Review Adopted Solutions

This last step will help Building Owners and FM Managers to evaluate if the adopted solutions are able to address the business objectives and smart FM outcomes identified earlier. It may also surface areas for improvement that can be taken into consideration when adopting other Smart FM solutions in the future.

Table 3 below shows how Building Owners and FM Managers can tabulate their findings to ascertain if the adopted Smart FM solutions have met their business objectives and desired FM outcomes.

<table>
<tr><th>Top 3 Business Objectives</th><th>Check Point</th><th>Desired FM Outcomes and Corresponding KPIs</th><th>Evaluate Adopted Solutions</th><th>Recommended Areas for Improvement</th></tr>
<tr><td>Cost</td><td rowspan="3">E.g.
Desired Outcomes and KPIs Achieved?

Are the Smart FM solutions adopted effective?

What went well or wrong?

Which area can be improved?

How can it be improved?</td><td>E.g. To reduce energy cost by 10% by 2022</td><td></td><td></td></tr>
<tr><td>Customer satisfaction</td><td>E.g. Increase user satisfaction on general area cleanliness and reduce complaints by 20%</td><td></td><td></td></tr>
<tr><td>Productivity</td><td>E.g. Increase internal FM staff productivity due to headcount freeze and ageing workforce
Increase productivity by 15%</td><td></td><td></td></tr>
</table>

Table 3. Sample table to review if the adopted solutions have addressed desired FM outcomes

Explore Further Opportunities

After the review, Building Owners and FM Managers can continue to explore further opportunities. This can be done by re-visiting:

- Step 1 – To verify if business objectives, desired FM outcomes and FM service priorities have changed;
- Step 2 – To check if new and emerging Smart FM technology solutions in the market can help provide better service; and
- Step 3 – To evaluate if a different implementation model(s) should be adopted; and whether the system and technical requirements to be specified in the procurement contracts needs to be enhanced.
- Step 4 – To review and better define the outcome-based measurements that can help improve the service quality of the FMCs or Service/ Solution Providers.

What Should Building Owners and FM Managers Consider in Step 5:

- Has the adopted Smart FM technology solution been well implemented and integrated within my existing FM processes and systems?
- Has it addressed the business objectives and desired FM outcomes earlier identified in Step 1?
- What are the tangible benefits and issues of each adopted solution?
- Are there areas for improvement that can be taken into consideration when adopting other Smart FM solutions in the future?
- Have the business objectives, desired FM outcomes and high-priority FM services changed?
- Are there new technology solutions in the market that can span across various FM services and better meet my needs?
- Do the high-priority FM services need to be changed to other types of "smartness"?
- Do I need to review and change the outcome-based measurements to better meet the needs/ requirements of various stakeholders?

Chapter 3. Digitalisation Maturity Map

3.1 Digitalisation Maturity Map

Although many FM stakeholders and companies have adopted Smart FM technology and/or practices, minimal progress has been made on system-to-system integration. There is hence a need to align the different levels and systems of digital adoption carried out by the industry so greater insights can be obtained and synergy within and across the FM value chain can be optimized. The Digitalisation Maturity Map encourages stakeholders across the value chain to co-share and integrate their data to achieve the following objectives:

a) Improve operational efficiencies on site;
b) Improve performance and productivity of the sub-contractor workforce;
c) Cost optimization through insights gathered from trend analysis; and
d) Improve quality of maintenance services provided from the analysis derived from data collection.

The Digitalisation Maturity Map seeks to map out and align the level of digital maturity across the FM industry, spanning across 3 Categories of FM stakeholders, including:

- Category 1: Digitally Ready **Vendors**
- Category 2: Digitally Ready **Facilities Management Companies ("FMCs")**
- Category 3: Digitally Ready **Building Owners**

Vendors, FMCs, and Building Owners may use the respective roles in Section 3.2 to chart their own digitalisation journey. As each plays a critical part of the FM ecosystem, the FM Digitalisation Relationship Mind Map (Figure 7) and section 3.4 describe the interaction and data exchange between these 3 digital entities to cohesively delivers the benefits of FM integration and aggregation.

3.2 Digitalisation Maturity Map: The 3 Categories

3.2.1 Category 1: Digitally Ready Vendors

Category 1 represents the vendors and contractors providing all the necessary FM services such as cleaning, pest control, and security. For them, digitising would mean to collect and process daily site data or feedback into useful information that can help to improve business operations.

There are *three* stages these service providers must take to embark on the digitalisation process to improve resource and process efficiency.

Category 1.1: Sense and Capture

Sensing and capturing data allow vendors to digitise information for better collection and control. This can be done through sensing technologies such as Internet of Technology (IoT) or smart devices, surveillance and/or video analytics technologies, inventory and asset registry, document management systems, and maintenance and audit logs.

For example, pest control providers may use smart devices such as smart mosquito and rat traps to improve their services, while security contractors may utilise CCTVs and access controls in their security operations.

'Schindler Ahead' is a real-world remote monitoring system that can detect any abnormalities or problems in Schindler's lifts. KK Women's and Children's Hospital (KKH) also uses KONE to monitor equipment performance remotely.

Category 1.2: Adaptive Actions

Vendors may translate data into actions and operation outcomes via incident management systems, and feedback/alert and response management systems, and workflow management/automation systems.

Data and alerts captured by the smart devices mentioned in Category 1.1 would be transmitted to the respective management systems utilised by the pest control and security vendors. Through this system, management staff off-site can be alerted of any incidents or feedback and act accordingly.

In Schindler, each technician has access to a company mobile application that is linked to their 'Schindler Ahead' system, a remote monitoring system that can automatically dispatch technicians and provide suggested actions for them to take in repair works. Similarly, KONE collects and analyses data and can assist to alert technicians when a predictive service need is generated. This allows the switch from reactive maintenance to predictive maintenance, which can extend equipment life and reduce costs overtime.

Category 1.3: Resource Optimisation

To optimise resources, vendors may tap on the potential of data in achieving business outcomes through management systems for manpower, fleet, scheduling, and inventory.

For example, contractors may make use of the historical data collected to plan ahead and deploy more manpower and resources in certain areas that are more problematic.

A real-world example would be ‘Schindler Ahead’ which provides a holistic overview of all the elevators in the building (can be merged with owners’ Smart FM systems by using Schindler’s ‘CoLab’ toolbox).

3.2.2 Category 2: Digitally Ready FMCs

FMC will go through a similar digitalisation process and enabling supply chain management to ensure service delivery governance in the following stages.

Category 2.1: Integrated Service Management

FMCs should have an integrated service management to augment supply chain management with data. This data can be used to increase and enhance FM functions such as supply chain management, incident management, customer management, adjacent data management, service delivery (SLA/KPI) governance.

Examples of integrated service management include vendor procurement and management systems (computerized maintenance management systems, integrated workplace management systems etc.) and automatic performance report generators.

For instance, Yale NUS uses an ‘Integrated Performance Dashboard’ that contains multiple dashboards displaying Key Performance Indicators. It allows facility managers to track ‘live’ and outstanding cases and collects performance related statistics such as the officers’ response rate to close a feedback, which can then be used to generate real-time appraisal on staff performance.

It should be noted that it is also possible for the vendor's management system to trigger a direct alert to both the FMCs and owners concurrently (e.g., emergency alert for trespassing). The data and notifications from the management system of each individual trade would then be transmitted to the FMC centralised system, which is illustrated in Category 2 of Figure 7 below.

Category 2.2: Intelligent Insights

Intelligent insights can be achieved with the use of data analytics involving features such as data visualization, fault analysis, feedback analysis, trend analysis, and predictive maintenance.

Examples of data analytics technologies include operation dashboards, fault and feedback trackers, master maintenance schedules, and anomaly alerts. For instance, the automated reports generated by the FMC's centralised system can aid in developing intelligent insights by carrying out trend and fault analysis, presenting the data through dashboards.

'CoLab', the recently launched building integration toolbox and Application Programming Interfaces (APIs) platform by Schindler offers performance, contractual, and operational information to clients. The 'Integrated Performance Dashboard' from Yale NUS can help identify the most frequently occurring problems for analysis. Yale NUS also uses a real-time 'Campus Health Index' platform that aims to reflect the current state of its ease of maintenance, impact on customer service, staff performance standards, safety, and sustainability.

3.2.3 Category 3: Digitally Ready Building Owners

With the information and reports submitted by the vendors and FMCs, the building owner can then enable data aggregation at the portfolio level to facilitate data-driven decision making.

Building owners would be more confident in business decisions that are supported with statistics and professional insights and will be able to better predict any future obstacles to avoid and potential opportunities to capitalize on. In this way, information can aid in strategic long-term planning where building owners can align business decisions with their big picture goals and plans. Benefits may come in the form of better investments or purchases for the property, improved estate planning and safety, and ultimately reduced operational and maintenance costs.

Category 3.1: Integration and Aggregation

The integration and aggregation of information can provide a holistic overview for client's portfolio management. Clients may make use of various technologies and strategies to achieve this. Examples include portfolio management and benchmarking tools, GIS overlay, Location-based Data (e.g., Hotspots), asset management system, and data overlays. Other than incorporating technology, owners may also compare building performance across different portfolios and/or set targets for FMCs and vendors to achieve.

Following the examples mentioned in the earlier stages, the automated reports generated by the FMC containing insights and analyses will be transferred to the building owners under Category 3, increasing the ease of building management on a portfolio level.

CapitaLand implemented their 'Intelligent Building Platform' that can provide benefits such as visibility of their asset performance, KPI tracking, and predictive and continuous maintenance regime.

3.3 FM Digitalisation Relationship Mind Map

The stages mentioned above will come together cohesively as shown in the relationship mind map illustrated in Figure 7 below. This mind map shows the digitalisation relationship among the 3 categories so stakeholders can be clear on the flow of information and upstream/downstream actions in the Smart FM ecosystem.

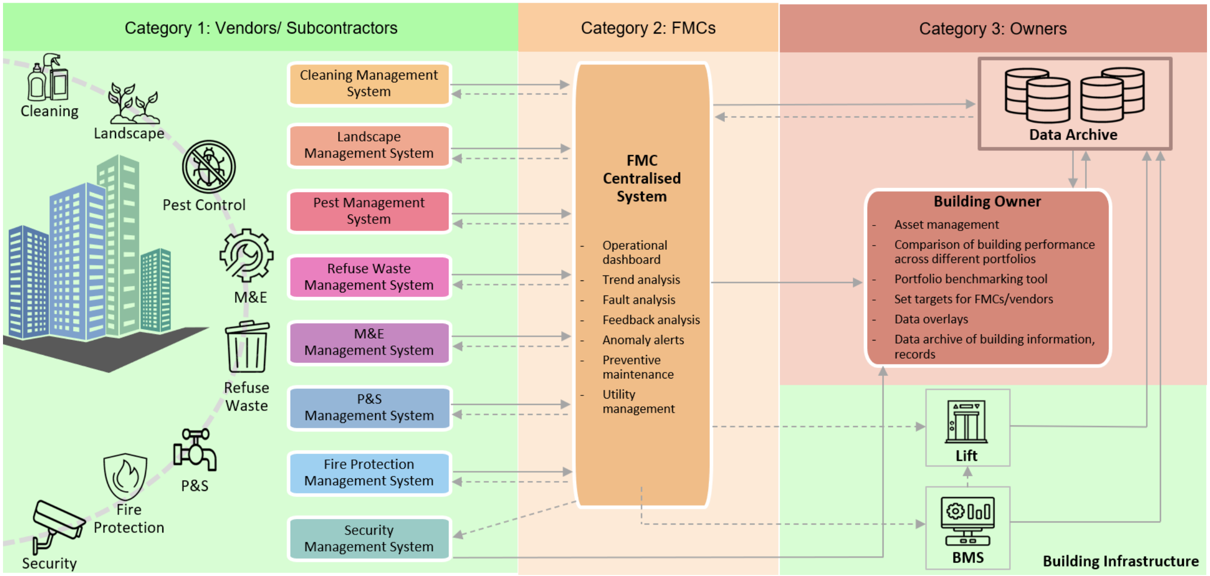


Figure 7. FM Digitalisation Relationship Mind Map

3.4 Digitalisation Maturity Map: Specific Trades

This chapter will illustrate the relationship between each Category by showing examples for each building trade.

3.4.1 Cleaning

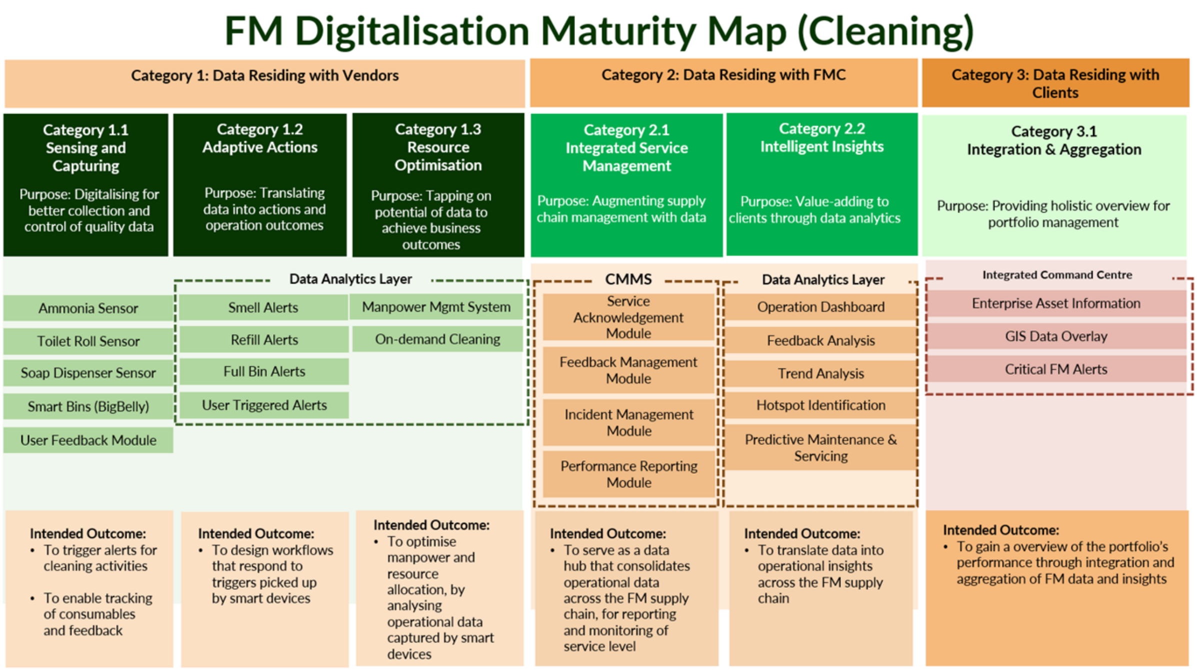


Figure 8. FM Digitalisation Maturity Map (Cleaning)

For cleaning, the smart devices under **Category 1.1** would be devices like ammonia sensors, soap dispenser sensors, smart bins, etc. that would help to trigger alerts for cleaning activities and allow ease of tracking of consumables and feedback. The readings from these sensors will then be sent to the vendor's system to trigger alerts for cleaning activities and tracking of consumables and feedback (**Category 1.2**). Insights generated through data analysis will enable the vendor to design workflows that respond to the alerts in appropriately. With these historical alerts and operational data, the cleaning vendor will be able to optimise the cleaning frequency, which aids in the scheduling of cleaners, and possibly enable an on-demand cleaning (**Category 1.3)**.

Moving on to Category 2, the cleaning data and 1st level analysis done by the vendor will be transferred to the FMC's centralised management system. Together with the information collected from other building trades, the FMC's centralised management system will serve as a data hub consolidating all the operational data across the FM supply chain (**Category 2.1**).

There can be various modules in the centralised management system including feedback management modules and performance tracking modules, which can help in reporting and monitoring the service levels of the FMCs and vendors. FMCs would also be able to perform data analytics, translating data into operational insights (**Category 2.2**). Numbers and trends can be presented through an operation dashboard to identify hotspots and show which building or location requires more attention.

Lastly under Category 3 for clients, data and insights provided by the FMC's centralised management system will enable operations and asset management on a portfolio level (**Category 3.1**).

3.4.2 Pest Control

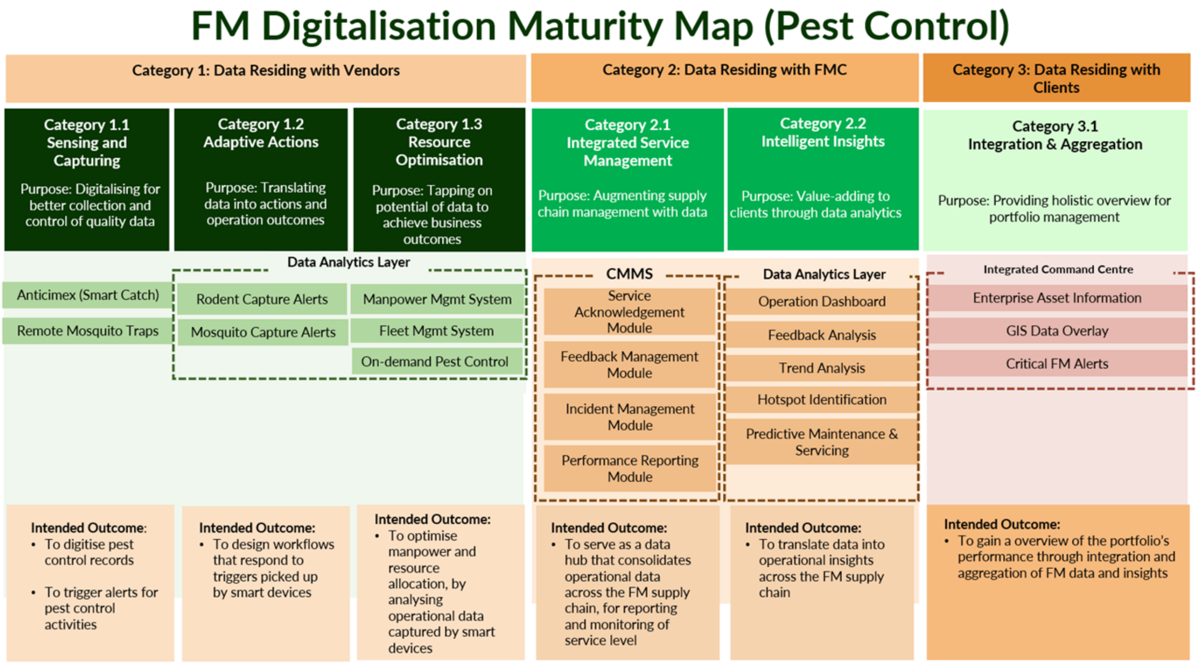


Figure 9. FM Digitalisation Maturity Map (Pest Control)

This section will only touch on Category 1 as Categories 2 and 3 will be the same as that outlined in the cleaning trade.

Smart devices for pest control would include detection systems and remote mosquito traps (**Category 1.1**). For example, the Anticimex SMART technology is a smart data hub that can monitor the movement of pests and send live notifications to the management system in the form of rodent or mosquito capture alerts (**Category 1.2**). Information collected would be the detailed location of where the rodent was caught, while insights generated may include identification of a hotspot area. Such data will allow the vendor to deploy resources more efficiently (**Category 1.3**).

3.4.3 Refuse Waste Management

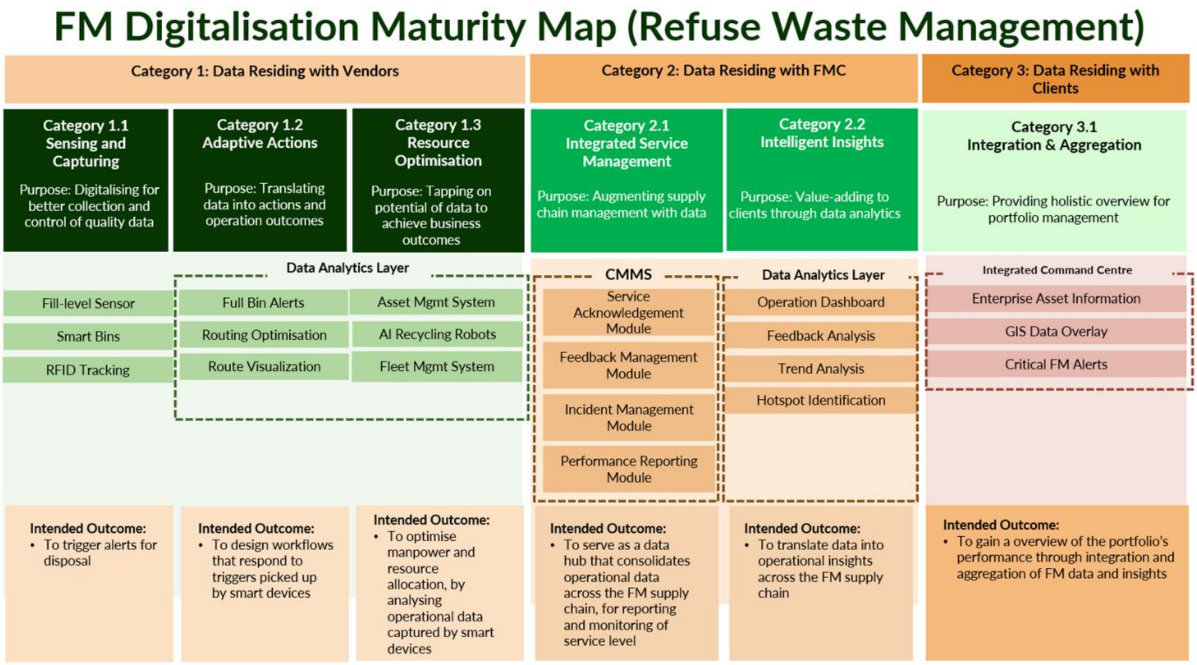


Figure 10. FM Digitalisation Maturity Map (Refuse Waste Management)

This section will only touch on Category 1 as Categories 2 and 3 will be the same as that outlined in the cleaning trade.

Smart devices used in this trade would include sensors measuring fill-level sensors, smart bins, and RFID tracking (**Category 1.1**). Fill-level sensors can be translated to full bin alerts, while the RFID tracking of bins allow for routing optimisation and route visualisation for management (**Category 1.2**). An asset and fleet management system can be set up to optimise resources (**Category 1.3**).

3.4.4 Landscape

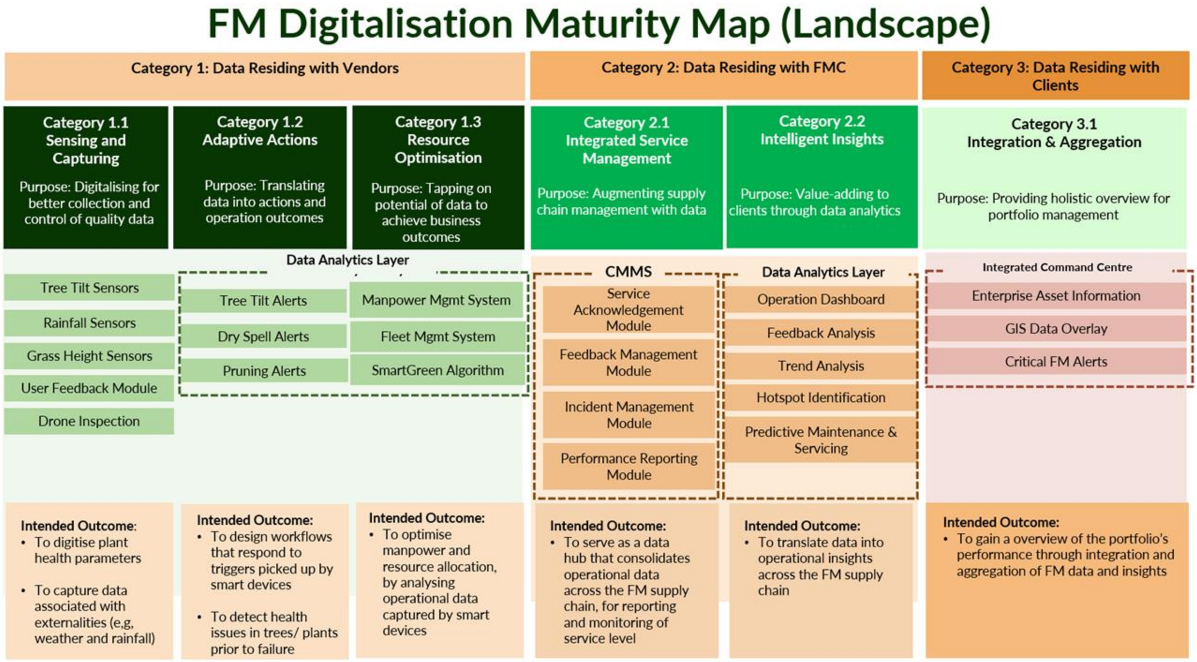
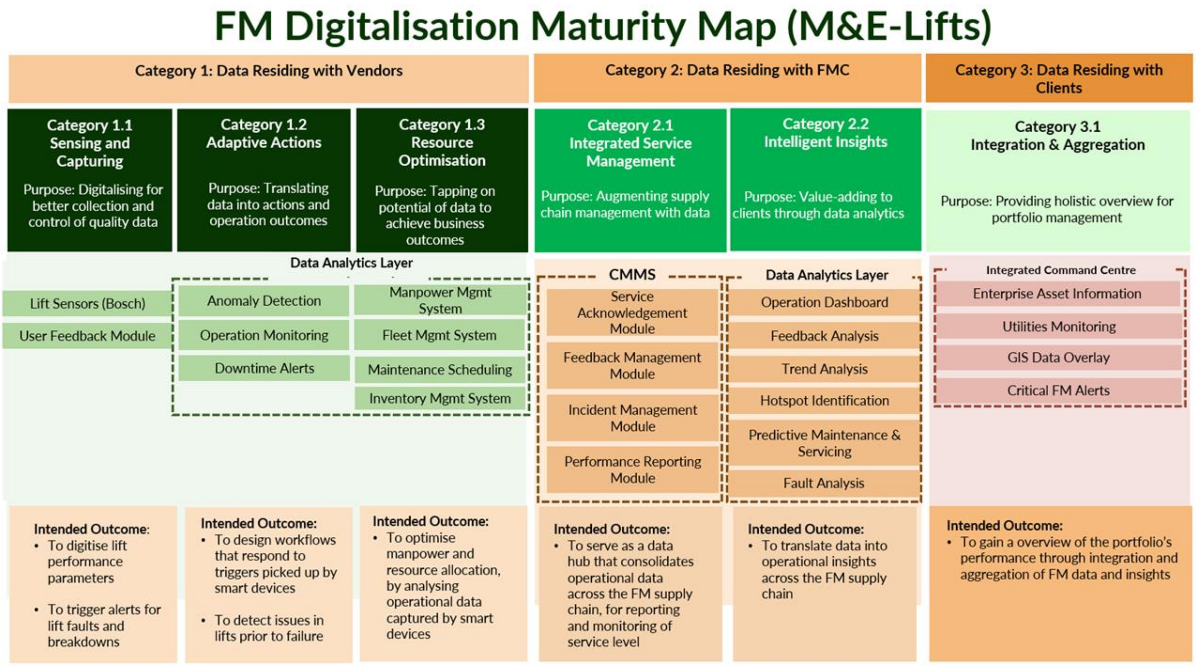


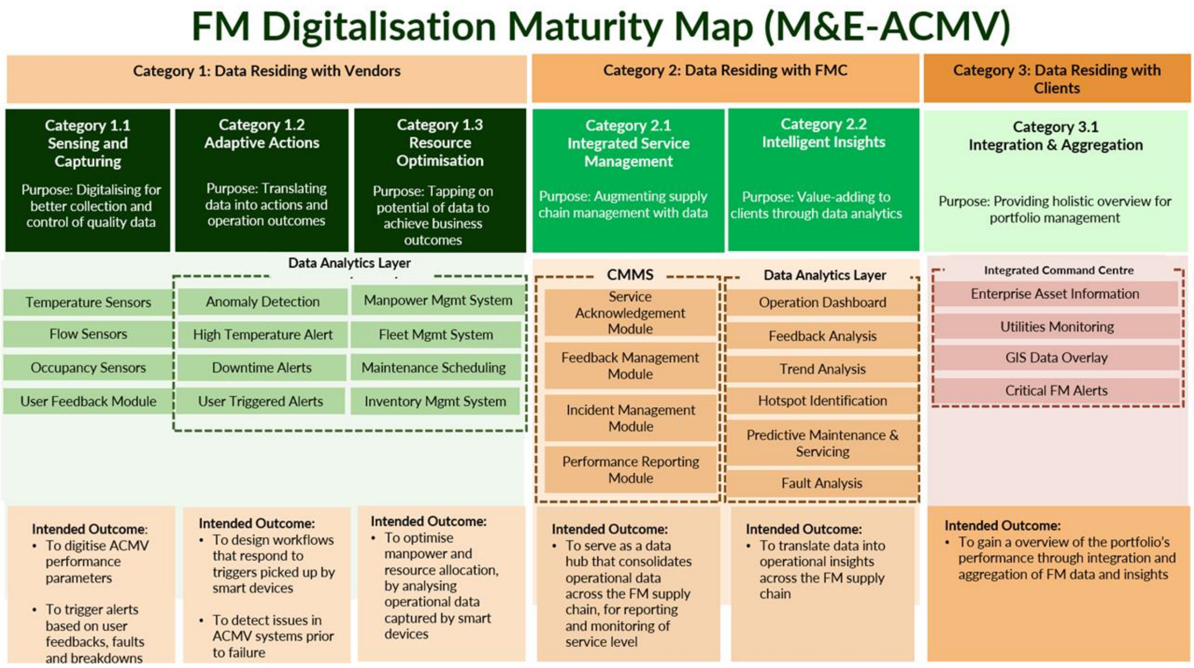
Figure 11. FM Digitalisation Maturity Map (Landscape)

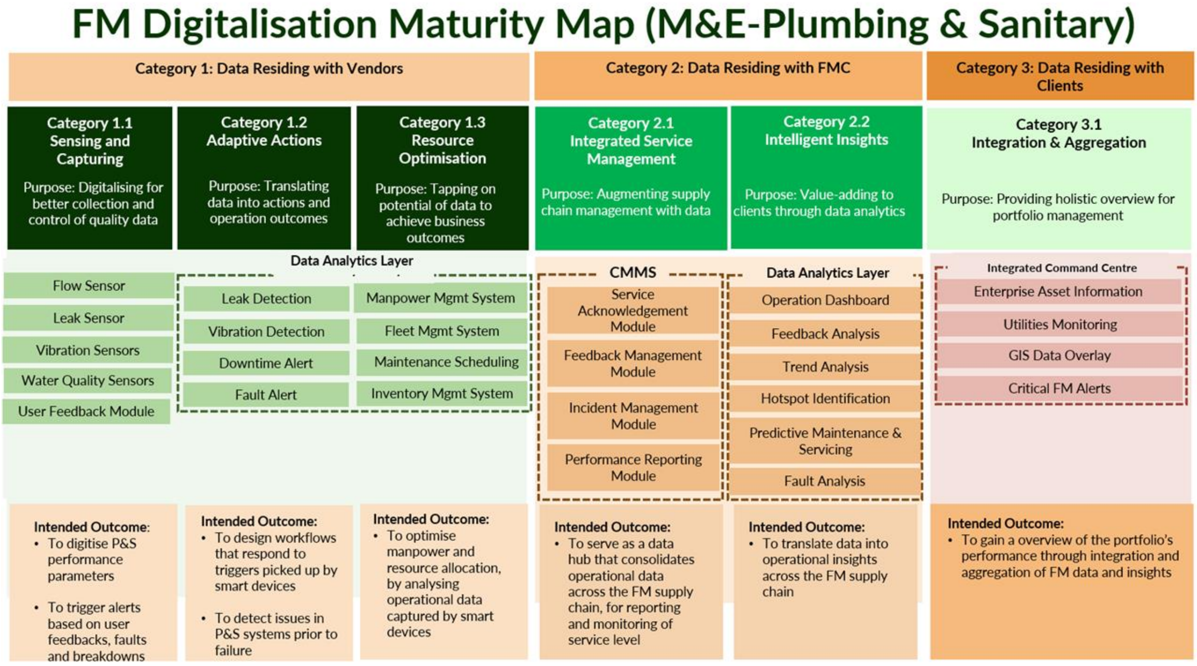
This section will only touch on Category 1 as Categories 2 and 3 will be the same as that outlined in the cleaning trade.

Smart devices used in this trade would include sensors measuring tree tilt, rainfall, and grass height, or drones that may aid in arborist inspections (**Category 1.1**). These smart devices can help in manpower scheduling and may also capture data associated with external factors such as weather or rainfall. Should a tree exceed any pre-allocated parameters assigned in the sensor, alerts will be generated and sent to the system (**Category 1.2**). The vendor then may plan for pruning or tree removal works in response. This system will hence aid to detect health issues in trees prior to actual failure and can reduce a lot of downtime and resources spent on-site. Resources may be better optimised via a manpower or fleet management system (**Category 1.3**).

3.4.5 M&E: Lifts, Air-Conditioning & Mechanical Ventilation, Plumbing & Sanitary, Fire Protection







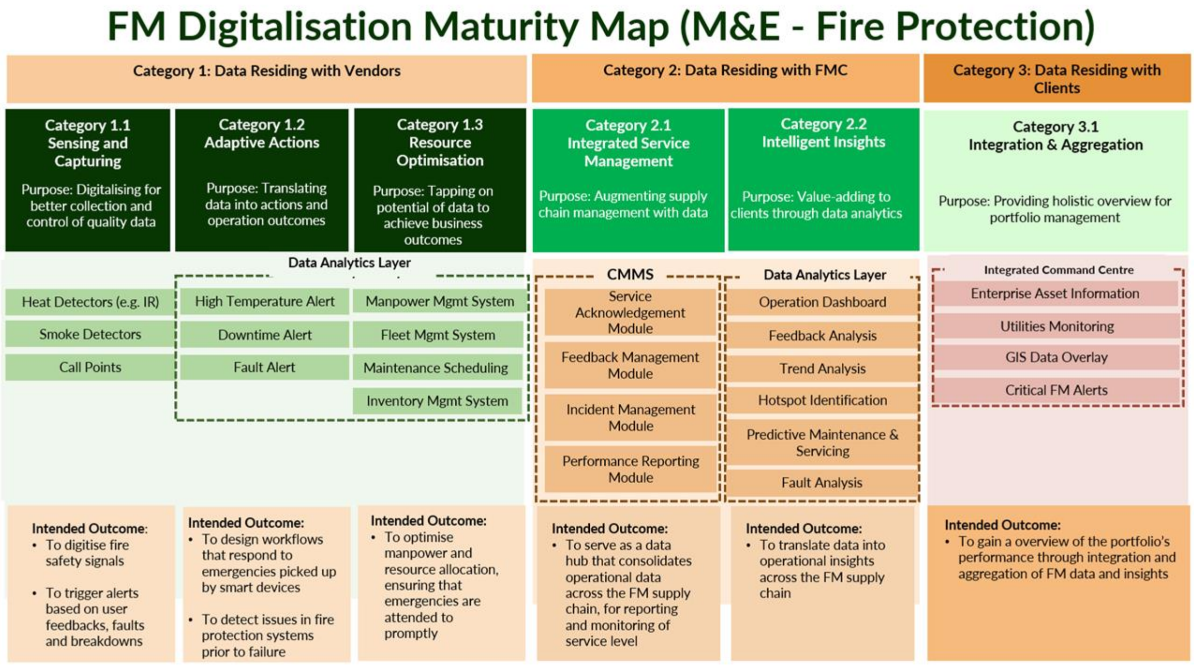


Figure 12. FM Digitalisation Maturity Map (M&E)

Under **Category 1.1** for M&E, smart devices largely include various sensors (lift sensors, temperature and occupancy sensors, water leak and water quality sensors, heat, and smoke detectors) and user feedback module where building users may submit feedback of lift breakdowns or water seepage. These data will again be sent as alerts through the system, with the common ones being in the form of anomaly detection, downtime alerts, or user triggered alerts (**Category 1.2**). M&E vendors will then use such information to plan and schedule for regular or ad-hoc maintenance works, as well as to manage manpower and equipment.

When these information and reports are submitted to the FMC's centralised management system, data consolidation and management will kick in. Feedback management modules to respond promptly to user feedback, or incident management modules to draft incident reports for building owners, may be implemented via automatic design workflows (**Category 2.1**). Insights such as analysis on common feedback and faults can be generated automatically as well with data analytics (**Category 2.2**). Numbers and trends can be presented through an operation dashboard and hotspot identification to show which building requires more attention.

These insights submitted to building owners may then be transformed into more comprehensive reports that can refine their overall perspective on the health of the property (**Category 3.1**). For instance, owners may track and monitor the building water consumption and trace high expenditures to water pilferage based on information and reports submitted by the FMC.

3.4.6 Security

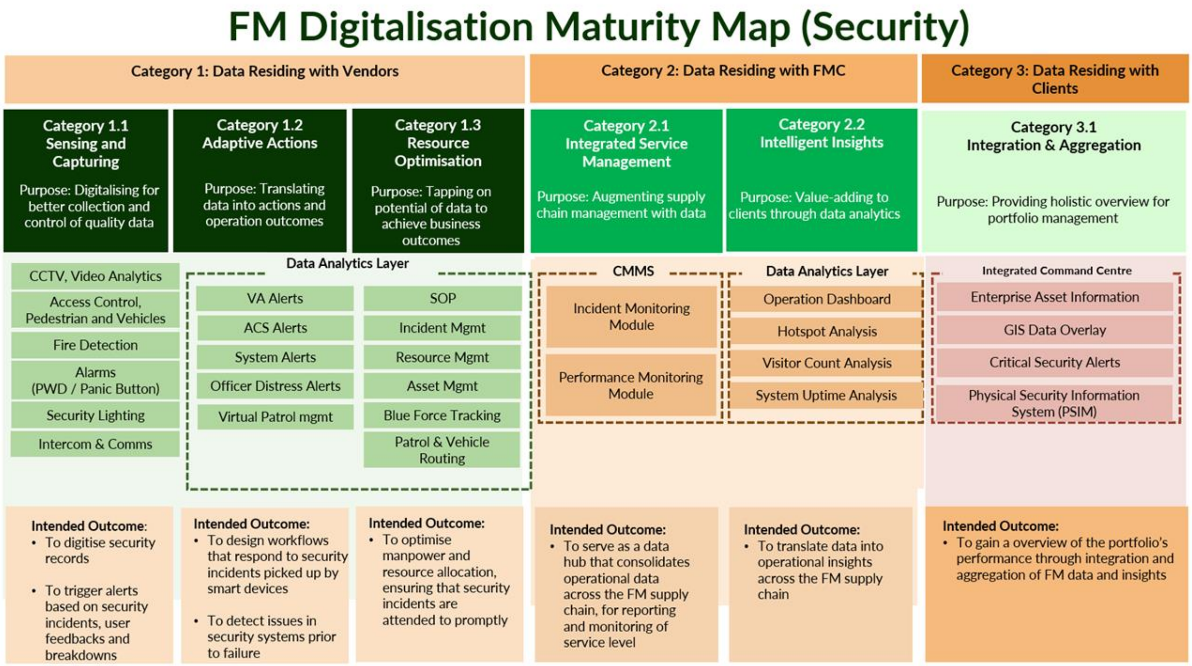


Figure 13. FM Digitalisation Maturity Map (Security)

Security vendors frequently incorporate smart devices such as CCTV cameras, video analytics, access control, and alarms in their operations (**Category 1.1**). Some of these smart devices may digitise security records and reduce downtime usually spent on administrative work. Trespassing incidents may be reported immediately with the use of access control and alarms, and alerts can be sent immediately and concurrently to the vendor's system. Under **Category 1.2**, the security vendor can design workflows that respond efficiently to security incidents picked up by smart devices. They may then optimise their manpower and resource allocation through implementing Standard Operating Procedures (SOP), incident or asset management, and patrol and vehicle routing (**Category 1.3**). This ensures that incidents can be attended to promptly.

The security data completed by the vendor will be transmitted to the FMC's centralised management system, which may incorporate incident and performance monitoring modules. Together with the information collected from other building trades, the FMC's centralised management system will serve as a data hub consolidating all the operational data across the FM supply chain (**Category 2.1**). FMCs would be able to perform data analytics via analysis on hotspot, visitor count, and system uptime (**Category 2.2**).

This information provided to building owners will let them have a holistic overview of their property, and they may digest and process this information further with processes such as GIS data overlay or integrate it all together under the physical security information system (**Category 3.1**).

Chapter 4. Data Management in Type 3 Smart FM Solution

With the shift towards Integrated FM and Aggregated FM (IFM/AFM) contract, the adoption of Type 3 Smart FM solution (Integration across systems) becomes apparent. As described in Chapter 2, Type 3 Smart FM solution aims to optimise resource deployment and utilisation across many systems.

4.1 Data Management Across Systems is Key

Clear business cases are of paramount importance to justify the investment in time and resources to adopting Type 3 Smart FM solutions. Having sophisticated digital FM solutions do not help the organization if the products are not able to deliver operational and/or financial benefits. The ability to access and analyse data across systems and solutions quickly and easily is key in not only developing clear business cases but also the adoption of Type 3 Smart FM, failing which would render the adoption of the myriad of technologies financially prohibitive and operationally unfeasible. As such, the management of data across various systems, applications and operations is key in ensuring the smooth implementation of Type 3 Smart FM.

3 key considerations in managing data:

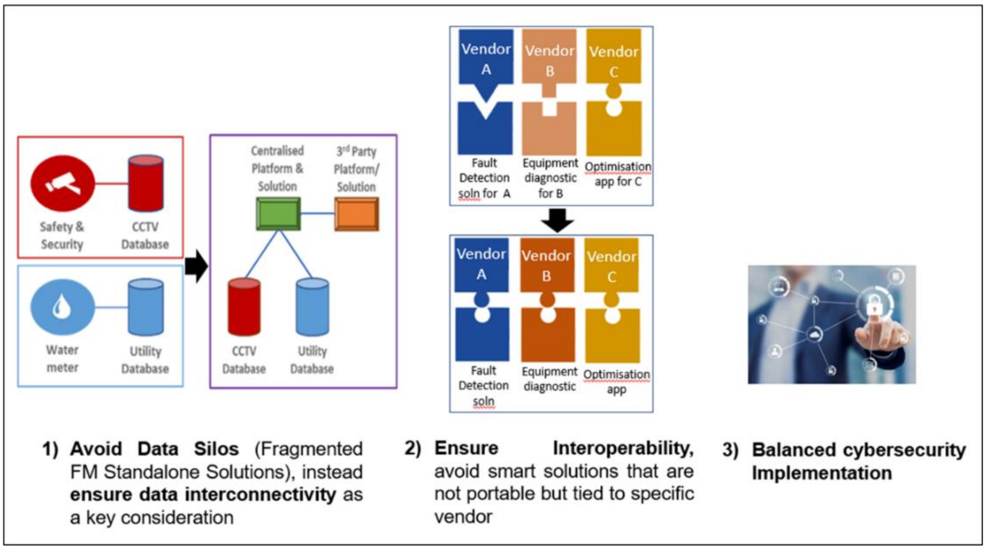


Figure 14. Key considerations in managing data

1) Ensuring Data Interconnectivity, Avoiding Data Silos

Bringing in data across multiple solutions enables the Facilities Management Companies (FMCs) and Building Owner to have a holistic view of their portfolio allowing them to know what is happening on the ground and make data-driven decisions.

It is important to consider the data connectivity of every solution and product prior to its implementation. Ensuring that implemented systems do not operate on stand-alone, closed/proprietary communication protocols is key in avoiding not only vendor lock-ins but also ensure that the necessary data that is required for decision making are available and accessible for use. Rectification of such a situation would not only be costly and time consuming but may also run the possibility that the entire solution would need to be replaced, just so that the necessary data is available to the organisation.

2) Ensuring Interoperability

Ensuring interconnectivity enables the ability to move data from one system to another system. This alone is insufficient in achieving automation between systems. The ability for a system to understand the meaning of the data that comes from other systems is referred to as interoperability (specifically data interoperability). For example, the correct interpretation of the data coming from a BMS point label "ZP.L1.ACMV.Z1.AIR_FLOW_2.FRESH" requires a mix of site-specific conventions and implicit domain knowledge. For 3rd party solution provider systems, deciphering its meaning is not an easy task, requiring extensive times and re-coding of the system to interpret the data for use. The issue of data interoperability becomes more pronounced for buildings with multiple smart systems that rely on data from each other and for building owners with multiple buildings in their portfolio which may have systems from a multitude of suppliers (e.g., multiple BMS vendors for multiple buildings) all using their own specific conventions.

3) Implementing Cybersecurity

Type 3 Smart FM solution relies heavily upon IT infrastructure to host and interconnect the various components of building systems. As with all IT infrastructure and systems, there is a need to ensure that the systems continue to function and are not hindered by external threats, especially systems that are connected to the internet. Cybersecurity is thus an important consideration for all smart building systems and owners should take the necessary precaution such as securing their network using network security device such as firewalls and ensuring that they are correctly installed, updated, and maintained. Other fundamental measures such as adopting a strong password combination, changing passwords regularly, installing an antivirus program and ensuring software are constantly updated and patched will help to reduce the risk However, there is a need to balance cybersecurity requirements vis-à-vis cost. It is important for building owners to review the criticality of each system and the sensitivity of the data it holds, balancing the need/level of security required.

4.2 Good Practices to Facilitate Data Management

4.2.1 Common Data Environment (CDE) for FM

A Common Data Environment (CDE) for FM can be established either by FM companies or building owners to manage information during operational stage of the assets. Such a CDE could potentially help address issues with data silos as well as interconnectivity as multiple systems' data and key information are consolidated into a single environment. Following ISO 19650-3 on Information Management during Operational Phase of the Assets (Clause 5.1.9), a CDE is defined as a ***combination of workflow and information storage solutions*** to support the information management process for the asset(s). To provide clarity on the CDE, the following guidance is added:

- A CDE is ***not necessarily a single large platform*** that interoperates with all other platforms used by all stakeholders, but rather a ***collection/consolidation of key information*** from the relevant technology stacks ***to manage specific***

use cases with the agreed mechanism[7] to exchange/share the information across the stacks. The CDE will thus be the main consolidator and distributor of these key information.

- As an example, a CDE can be consolidation of data from an IoT platform and FM workflow automation platform to support Fault Detection & Diagnostics (FDD) use case. In this example, the CDE can consolidate fault-related information (e.g., type of incident, location, etc) from the respective IoT platform and/or FM workflow automation platform to gain insights on the service level delivery by monitoring the time taken to close the incidents as well as the critical assets performance by monitoring the Mean-Time-Between-Failure (MTBF) of the assets.

As in the implementation of all enterprise level solutions, an organisation should go through a detailed business case review to determine its use cases, the data that it requires and thus value for the organisation. The functional requirements of the systems that a CDE should connect with would be determined through the business case review. Some common features/functionalities of CDE for FM are as follows:

- File and data management: It is important that data and information is made easily available in the CDE for both human users as well as systems. A data lake or data warehouse for data to be queried, viewed, extracted, and stored should be considered in tandem with data standards[8], data hierarchy, data types as well as frequency of use amongst many others.

- User management: Given that a CDE would be the source of information for many within the organisation as well as to selected few outside of the organisation, proper user management is required to ensure that data stays secure and that only the right people can access the right data for them. For example, building owners/FMCs might create access accounts for term

[7] Depend on how a use case is defined, the mechanism to exchange/share the information can be in a form of passing the key information through email/SMS or open communication protocol as described in Section 4.2.2.
[8] Data standards are documented agreements on representation, format, definition, structuring, tagging, transmission, manipulation, use, and management of data.

contractors service providers to only access data and services for which they are authorised. The access rights for this group would differ greatly from those given to their own staff. User access rights and management is also key in ensuring traceability of activities, changes and actions that are carried out in the CDE.

- Dashboard, analytics, and reporting: Having a wealth of data, it is important for the organisation to make sense of it to derive value. Business intelligence (BI) tools, such as dashboards and analytics tools would help the organisation understand and analyse its data, generate insights and build predefined reports on selected events (e.g., equipment breakdown) or assets (e.g., energy consumption) essential for operations. Doing so enables the Facilities Manager to better plan his Operations and Maintenance (O&M) schedules, optimise resources and identify areas to improve.

- Operation and workflow management: Managing operations and FM workflows are the foundation of any organisation involved in FM. Given that much of the data and decisions for FM either originate or end with operational task and an integral part of FM workflow, a CDE for FM should include functions and features around managing such tasks, this may include pulling and pushing relevant information to building owners, FMCs and other service providers for works to be carried out as well as tracking and overseeing feedback/maintenance/repair tickets.

- Open protocols: The use of open protocols as a foundation requirement of any CDE is important to ensure ease of interconnectivity between system. More on this will be shared in following sections.

- Cloud-based environment: Adopting a cloud-based environment will allow data and information to be efficiently accessed, shared, and maintained from any location, so long as there is an internet connection.

4.2.2 Open Communication Protocol

Communication protocols define how devices talk to each other; hence if a building has equipment/systems that use proprietary (closed) protocols, they will not be able to communicate with another system, without substantial effort and costs to convert the protocols to one that is common between the systems. As such, it is important that organisations mandate the adoption of open protocols as a foundation in the systems it adopts. Many different open protocols have been developed over the years; this multitude of choices mean that product manufacturers would need to decide which protocol(s) their products will conform to. In choosing a product, users would thus be inherently choosing and adopting the protocol(s) that come with it.

Building owners and FM companies should consider the following when choosing a product and the communication protocol requirements for it.

1. Consider the requirement for compatibility with existing systems and equipment. For example, an equipment monitoring system may require communication with a workflow system to automatically trigger cases when alarms are received. Choosing the right product and the inherent communication protocols it uses would determine the complexity of achieving this interconnectivity between the systems.
2. Consider the adoption rate of the protocol among different vendors that provide the solution/system. A protocol that is common amongst a large group of vendors providing the service not only increase the likelihood that other systems would have catered to this protocol but also provides flexibility to owners in changing system/vendors without impacting other systems that would have already been integrated.
3. Consider the need to add new devices or interconnectivity with additional systems in the future. Adopting a protocol that is widely adopted beyond a single discipline will enable scalability in the event where new devices and solutions need to be connected for new capabilities and further automation.

Several common open communication protocols and data transmission methods are as follows:

- Building Automation and Control Networks (BACnet): A communication protocol for Building Automation and Control (BAC) networks that leverage the ASHRAE, ANSI, and ISO 16484-5 standard protocol. It supports most building operations, such as ACMV, lighting, fire protection, and access control devices. The BACnet protocol provides services that are used to communicate between building devices. Examples of such services are Who-Is, I-Am, Who-Has, I-Have, which are used for Device and Object discovery. Services such as Read-Property and Write-Property are used for data sharing.

- Modbus: Modbus supports communication to and from multiple devices connected to the same cable or Ethernet network and is widely used in industrial, building, infrastructure, transportation, and energy applications.

- OPC Unified Architecture (OPC UA): able to communicate with major building automation protocols such as BACnet and Modbus; hence it can be thought of as a universal translator for linking disparate systems. It allows different systems such as security, lighting, elevator, and ACMV to be connected using a single connectivity standard.

- Application Programming Interface (APIs): is fundamentally a software intermediary that allows applications to talk to each other. It is a set of definitions and protocols for integrating application software and are used when required to perform a designed function built around sharing data and executing pre-defined processes. In FM terms, it could be used when a ACMV diagnostic software detects an anomaly, the diagnostic software calls the CMMS to create a job ticket where the issue will be track and manage by the technician in the CMMS.

- File Transfer Protocol (FTP): is a standard asynchronous communication protocol used for the transfer of files from a server to a client. For a more secured transmission, users should opt for SSH File Transfer Protocol (SFTP). Typically used when data size is large and is not required real-time. In FM terms, it could be used when transferring the list of people that enter/exit the building for the month from the Visitor Management System to the building owner's registry.

In addition to using open protocols to address interconnectivity issue, ensuring data accuracy and quality is also important. A way to ensure data accuracy and quality is to set the expected max value and the min value for a measured point. This allows the system to flag out anomaly. For example, for an office room temperature sensor, the max value can be set at 35 ºc and the min value to be 15 ºc. If the measured point is outside of the range, the technician can be informed to check the condition of the sensor.

4.2.3 Conventions and Schemas for Organising Data

Conventions and schemas ensure the consistency of data across systems. This comes into importance when an organisation has multiple similar assets it needs to monitor. An example of this is when a CDE or central monitoring system requires interoperability with multiple BMSes across different properties under an organisation. Having a common set of definition of how the data in the BMSes for every building is named and structured would significantly reduce the time, effort, and cost in making sense of the data across each building.

The recent ISO 21823-3 on Interoperability for IoT systems (Semantic Interoperability) highlighted the importance of ensuring consistency of the data across systems regardless of individual data format through the adoption of common metadata schema.

Having a common Metadata schema addresses data interoperability issue by:

- <u>Standardising the definition of a "thing" (controlled and shared vocabulary)</u>
  Example: some system suppliers (or building owners) may define zone as a group of multiple buildings but others as a group of multiple spaces or a separately controlled cooled space. Querying the data that do not adopt a common definition of a "thing" (in a metadata schema) may give inconsistent outputs that require further data cleaning before it can be used for analytics.
- <u>Standardising the relationships between "things"</u>

Example: to enable smart analytics such as Automated Fault Detection and Diagnostics, relationship between the "things" (e.g. AHU **feeds** fresh air to VAV, VAV **has** Damper, etc) need to be defined. Inconsistency in defining the relationship between "things" may hinder portability of the smart analytics from one machine or system to another.

While it is possible to define and create a metadata standard specific to an organisation, this may require significant investment in time and effort. Noting this, several open-source metadata schemas for buildings have become available and are gaining prevalence in the industry. It is important to note that an organisation should adopt a single schema and stick to it, having different schemas within an organisation portfolio would erode the synergy that adopting a metadata schema brings. Some of these are as follows:

- Brick Schema (https://brickschema.org/): standardise semantic descriptions of the physical, logical, and virtual assets in buildings and the relationships between them.
- Project Haystack (https://project-haystack.org/): standardise semantic data models and web services with the goal of making it easier to unlock value from the vast quantity of data being generated by the smart devices.
- Digital Buildings Project (https://google.github.io/digitalbuildings/): a uniform schema and toolset for representing structured information about buildings and building-installed equipment. A version of the Digital Buildings ontology and toolset is currently being used by Google to manage buildings in its portfolio.

4.2.4 Cybersecurity for Smart Buildings

The Info-communications Media Development Authority (IMDA) published the *Internet of Things (IoT) Cyber Security Guide* in Mar 2020 to provide users and enterprises with essential guidance when procuring, deploying, and operating IoT devices and systems. This guide also enables FMCs and Service/Solution Providers to verify the security posture of their solutions. It includes practical guidelines featuring baseline recommendations, foundational concepts, and checklists, alongside an annex[9] (Annex C) containing a Case Study for Smart Buildings. This annex serves as a valuable reference for Building Owners, FM Managers, FMCs, and Service/Solution Providers aiming to implement and operate IoT devices and systems securely.

In modern smart buildings, which integrate complex autonomous building automation systems, the risk of cyber-attacks is significant if these systems are not properly secured. The Technical Reference (TR) 111 on *Securing cyber-physical systems for buildings*[10] offers a comprehensive overview of asset management, physical and environmental systems, and access control related to building systems.

To further enhance cybersecurity, the Cyber Security Agency (CSA) has developed a certification scheme[11] to recognise organisations that demonstrate good cybersecurity practices. The Cyber Essentials mark acknowledges organisations that have implemented essential cyber hygiene measures, while the Cyber Trust mark is a distinction for those with comprehensive cybersecurity strategies and practices. These marks serve as visible indicators, demonstrating that organisations have established robust cybersecurity measures to protect their operations and customers from cyber threats.

4.3 Use Cases for Data Management

A use case can be defined as a list/sequence of actions that an actor (a person or other external system) performs within a building system to achieve a particular goal. It is an effective way for identifying FM processes and functional requirements, especially useful in prioritising the scope of work for complex processes with large numbers of possibilities and stakeholders.

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[9] The annex is available at: https://www.imda.gov.sg/-/media/imda/files/regulations-and-licensing/regulations/consultations/2022/consultation-for-new-annex-c-of-iot-cyber-security-guide/imda-iot-cyber-security-guide-annex-c-final.pdf

[10] TR111 is available for purchase via the Singapore Standards website: https://www.singaporestandardseshop.sg/Product/SSPdtDetail/98cf35ec-5e5b-4850-a0f5-04fa148aac29

[11] More detail at: https://www.csa.gov.sg/our-programmes/support-for-enterprises/sg-cyber-safe-programme/cybersecurity-certification-scheme-for-organisation

The proper management of FM data, ensuring data interconnectivity, avoiding data silos, ensuring interoperability, and implementing cybersecurity, unlocks opportunity for enhanced capabilities (or use cases) in FM. The following sub-sections explore specific use cases , with additional examples available in Appendix F.

4.3.1 Workflow Tracking and Service Level Delivery

Workflow tracking and service level delivery is essentially the consolidation and analysis of data pertaining to works detected and carried out within a building or multiple buildings. Traditionally, building owners with multiple buildings would procure a solution similar to that of a CMMS to create, track, and process such works with their service providers being required to use this procured solution. However, for some building owners, such methodology might be more costly and not a business focus. On the other hand, facility management companies (FMCs) would typically have a CMMS as an essential part of their core business. Building owners can thus obtain synergy through proper data management and leveraging the CMMS of the FMCs.

Building owner may consider establishing a cloud data management platform to hold, process and track such workflow data. Key information on works, such as completion duration, costs, material/part replacement, etc. can be transmitted over from the FMCs to the data platform and where the building owner can use the information for reporting, tracking, analytics, and decision making. Such a methodology would not only save costs for building owners but also save time in maintaining and ensuring uptime for a CMMS as well as in training their service providers to use an unfamiliar system. This frees up and allows building owners to better look into correlating data across services to better understand and optimize the building, e.g., correlating equipment runtime with maintenance regime and part replacement / breakdown.

4.3.2 Fault Detection and Diagnostics

Fault Detection and Diagnostics (FDD) is the process of detecting deviations from normal or expected operation (faults) and diagnosing the type of problem and/or its location. FDD technology is seeing an increased uptake in the market today that aims at improving building performance in different areas such as optimising energy efficiency, reducing utility expenses, and streamlining operations & maintenance processes. However, to realise the full potential at scale, some technical barriers must be addressed as discussed below.

Building equipment data is traditionally stored and processed within a building's BMS. Traditional BMSes monitor equipment data to ensure the functional operation of the building, flagging out critical alerts when a breakdown occurs. Such equipment data have a myriad of potential uses when analysed at system level and with complimentary data outside of the equipment itself. However, such equipment data are typically locked up within the BMS and difficult to extract and make sense of. This is compounded when building owners have multiple buildings with different BMS brands.

Adopting a standard convention/schema for equipment data within different BMSes would ease the ability to make sense of the data across different brands. Centralising this data into a single environment would enable not only the ability to trend performances across equipment types but also provide visibility on differing ways each building is managed on the ground.

It is good to note that centralising raw equipment data might be costly simply due to the sheer volume of data. One method around this is to enable a certain amount of processing and consolidation at the edge before the data is being sent to a CDE. For example, if the use case is to analyse the data over the year, there may not be a need for data points of every second, rather an average over a day may suffice. Newer BMS systems today would also offer equipment analytics at the BMS level before the information is transferred to a CDE.

4.3.3 Condition-based Maintenance

Condition-based maintenance is a predictive maintenance strategy where various elements of an operating asset are observed and measured over time to identify potential failure before it happens. While condition-based maintenance can be adopted on most assets, it is important to focus more on the most critical assets to achieve the best return of investment.

The following are some techniques used in condition-based monitoring:

- Vibration analysis: identifying potential failure by observing changes in vibration signature. For example, when compressors or motors degrade or fall out of alignment, the intensity of the vibration increases.
- Infrared and thermal analysis: using Infrared cameras and/or thermal sensors to determine when an equipment (e.g., motorised parts that operate at high RPM) become too hot and alerting the maintenance team before it burns out or starts a fire.
- Electrical analysis: using clamp-on ammeters to measure the electrical current in a circuit which may cause problems for an asset.

Some of these techniques can also be combined to gauge the health of an asset.

Analysing equipment data in tandem with maintenance cycles would help paint a picture of equipment reliability. Understanding how maintenance affects equipment data as well as what normal operational data looks like would help enable the development of condition-based maintenance strategy where maintenance cycles can be extended and, in some cases, only done on demand when required to prevent breakdown/deterioration.

Chapter 5. Digital FM Workforce

Smart FM refers to the integration of processes, technologies, and people to enhance the management of a building's facilities. Thus, it is important to not just focus on sourcing and implementing technologies, but also equipping the people with the required understanding of why, when and what technologies should be used and how to use them effectively. More often than not, the application of technologies can make the work more efficient to yield better results. However, as the saying goes "Use the right tool for the right job".

A lack of understanding on when, what, and how to utilise the right tool may eventually lead the users to develop negative connotations such as frustration and confusion, towards digitalisation. Consequently, this may lead them to believe that they are incapable of navigating the complexities of technologies and eventually choose to avoid them as much as possible. Therefore, this chapter aims to guide the readers towards a meaningful and practical approach to build up digital capabilities of the workforce in various relevant roles within Facilities Management.

A 4-step process, shown in Figure 15 below, is recommended to aid the organisation in developing their digital capabilities.

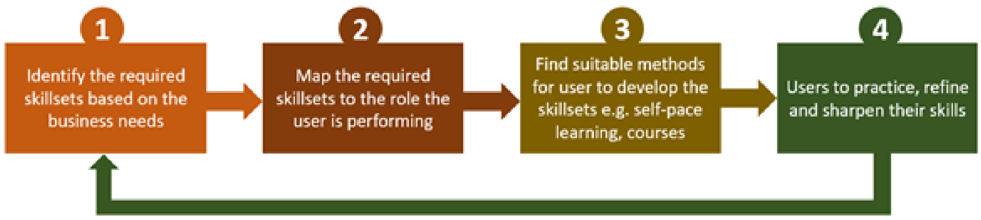

Figure 15. 4-step process in developing digital capabilities

Step 1: Identify the required skillsets based on the business needs

The FMIC and its taskforces have identified a list of digital skillsets that are relevant for Facilities Management today to support integrated and aggregated FM and mapped them to 10 Technical Skills and Competencies (TSCs) under the Skills Framework (SFw). The areas are listed in the table below:

SN	TSC	Description
1	Technology Scanning	Review new developments in emerging technology as well as evaluate and determine relevance of emerging technologies to the organisation
2	Robotic and Automation Technology Application	Integrate robotic and automation technologies in the Built Environment, including construction, operations and maintenance to enhance productivity and precision and to reduce reliance on manual tasks
3	Internet of Things Management (available in SFw-BE, to be added under FM track)	Interrelate computing devices, equipment and machines data in a networked environment to provide specific solutions
4	Technology Application	Integrate technologies into business operations of the organisation to optimise efficiency and effectiveness of processes
5	Applications Integration (available in SFw-BE, to be added under FM track)	Integrate data or functions from one application program with that of another application program - involves development of an integration plan, programming and the identification and utilisation of appropriate middleware to optimise the connectivity and performance of disparate applications across target environments
6	Smart Facilities Management	Integrate digital technologies and smart automation into facility operations and maintenance to optimise efficiency and performance
7	Data Collection and Analysis	Collect, extract and interpret data according to defined requirements to obtain insights
8	Design Thinking Practice	Manage design thinking methodologies and processes to solve specific challenges, and guide stakeholders through the phases of inspiration, ideation and implementation
9	Integrated Digital Delivery Application	Drive the adoption, integration and implementation of Integrated Digital Delivery (IDD) technologies to manage projects and building life-cycle efficiently from digital design, digital fabrication, digital construction to digital asset delivery and management
10	Cybersecurity	Understand, develop and apply cybersecurity policies and procedures to ensure protection against cybersecurity risks and vulnerabilities, and to respond to cybersecurity breaches

Table 4. Technical Skills and Competencies (TSCs) under the Skills Framework (SFw)

Step 2: Map the required skillsets to the role the user is performing

In building up digital capabilities, organisation should also avoid taking a "one size fit all" approach and overload the ground operations personnel with capabilities that may not be required for his/her scope. Instead, organisations should adopt a proactive approach to tailor the proficiency level to the needs of the role that the individual is performing. "*The right person, in the right job, with the right skills, at the right time*".

In this example, the guide will adopt the SFw career pathway for the Built Environment sector as an example. Based on the SFw Job Role, the level of competencies can be broadly mapped into 3 groups targeting those in the Senior Management, Middle Management and Operational team. The example will map the skillsets to the 3 groups based on their respective needs.

SFw Job Role	Possible Job Title/Designation	Group
Associate Director	• FM Director • Associate Director (Admin and FM) • Deputy Director (Building Services)	Senior Management
Senior Facilities Manager	• Senior Facilities Manager • Senior Fire Safety Manager • Senior Digital FM Specialist[12]	Middle Management
Facilities Manager	• Facilities Manager • Fire Safety Manager • Digital FM Specialist	
Technical/Building/ Facilities/Property Executive	• Technical Executive • Building Executive • Facilities Executive • Property Executive	Operational Team
Technical/Building/ Facilities/Property Officer	• Technical Officer • Building Officer • Facilities Officer • Property Officer	
Facilities Technician / Building Supervisor	• Facilities Technician • Building Supervisor	

Table 5. SFw Job Role matched to the respective groups

[12] Digital FM specialist/Digital Service Officer to develop the technology road map, manage the technology implementation and integration, perform data analytics and optimisation for equipment, manpower, and resource.

Technical Skills and Competencies	**Areas of Focus** *(by industry partners)*	**Level of Competencies** *(by industry partners)*		
		Senior Management	Middle Management	Operational Team
Data Collection and Analysis	Data Strategy Data Quality Mgmt Data Engineering Data Governance Master Data Mgmt	• Overview on how data should be collected, stored, and managed. • Principles of Data Management	• Utilise appropriate tools, systems, and techniques to collect, store, extract, transform and load data according to set guidelines. • Develop data management structures, policies, processes and tools for effective data storage, handling, and utilisation. • Implement data management processes and systems to map data sources, processes, and relationships, and transform and process multiple streams of data.	• Understand the need to input accurate data to facilitate upstream analytics and reporting.
	Predictive Analytics Fault Detection & Diagnosis Artificial Intelligence Machine Learning	• Strategic understanding on the various tools and techniques for data analytics	• Understanding of how analytics is used to detect, identify, and diagnosis anomalies. • Identify underlying trends and patterns using basic statistical analysis and business intelligence tools. • Develop, apply and evaluation algorithms, predictive data modelling and data visualisation to identify underlying trends and patterns in data. • Lead the procurement of advance/proprietary analytics software.	• Able to troubleshoot and act on the diagnosis of the model.

			• Develop operational workflow when fault arises. • Analyse results and work with FM operations to troubleshoot faults or optimise building systems.	
	Dashboards & Reports	• Overview of various visualisation tools available in the market and benefits of them • Navigate and use the tools available to track the organizations performance • Assist in strategic decision making	• Generate dashboards and reports to reflect data trends, findings and to facilitate management reporting • Utilise tools to identify focus areas to work on • Establish effective data visualisation architecture, process and system integration to get the necessary data. • Provision of tools, data and techniques to create dashboards	• Able to utilise dashboards and reports to identify areas to work on e.g. outstanding tickets
Internet of Things Management	IoT Architecture Technology Fundamentals M2M Communications Network Protocols	• Strategic understanding on objectives and key functions of IT/OT systems and System-of-systems • Formulate Internet of Things (IoT) direction and platforms so to drive operational efficiency and effectiveness	• Understanding on objectives and key functions of IT/OT systems and System-of-systems • Identify or develop solutions to improve automation and productivity • Determine use cases, user and data requirements for FM systems • Detailed understanding on IoT protocols and technology stacks • Wired & wireless communication technologies • Concepts of system scalability, interoperability, availability and reliability	• Fundamental understanding on Ops Tech

			• Sensor and controller reliability concepts	
	Digital Twin BIM for FM	• Identify trends, technologies in the development of 3D operational models • Overview on the principles, value proposition, requirements, components of BIM and integration of any visualization solutions • Strategic understanding on the technology used in BIM and BIM design processes, standards, and implementation strategies to allow remote access	• Identify trends, technologies in the development of 3D operational models • Overview on the principles, value proposition, requirements, components of BIM and integration of any visualization solutions • Technology used in BIM and BIM design processes, standards and implementation strategies. • Process and methodology in the development of 3D operational model • Connecting and integration multiple building services into a single facilities platform. • Execute technology used in BIM and BIM design processes, standards, and implementation strategies.	• Able to open, utilise the Digital Twin / BIM for FM tool for day-to-day operations.
Smart Facilities Management	Cloud BMS Automation	• Strategise the application of digital facilities and smart automation in different functional areas and processes	• Manage facility operations and maintenance with digital technologies and smart automation • Integrate digital technologies and smart automation into facility operations and maintenance	• Support facility operations and maintenance with digital technologies and smart automation

			• Develop facility operations and maintenance procedures for integration into smart automation and operation technologies	
Design Thinking	User Interface User Experience Design Thinking	• Understanding the principles in UI and UX/Design Thinking • Design thinking methodologies	• Streamline processes & workflows and utilise process automation tools to enhance FM efficiency • Understanding the principles in UI and UX/Design Thinking to enhance user experience • Apply design thinking methodologies and execute design thinking processes to challenge norms and conventions • Design information architecture, process flow, and user interface prototypes • Create user experience design concepts, develop user flow charts • Translate key user experience concepts and guidelines into simple wireframes • Establish effective design thinking processes, methodologies and frameworks to proliferate design thinking	
Technology Application	Digital Transformation Digital Strategy Digital Marketing	• Formulate technology strategies for business operations and processes, and	• Execute Digital Transformation Roadmap • Implement technology plans and supervise the use of technology to execute tasks	• Adopt new technologies to enhance operations or processes • Digital Confidence for IoT and Cybersecurity • Digital Confidence for Productivity

	Digital Communication strategies Change Management: “Digital” + “facilities”	design plans for implementation	• Review the practicality, feasibility and risks of new technologies in relation to business processes • Develop plans to implement cloud solutions • Deploy cloud solutions and resolve basic cloud integration issues • Familiarity with Cloud Service Providers, Programming languages and Database Query Languages	• Use of Web and Mobile App for FM
Technology Scanning	Emerging technologies Cloud Solutions Cost-benefit analysis for technologies implementation	• Inspire adoption of emerging technologies to enhance organisational effectiveness and competitiveness • Identify trends and technologies in cloud solutions • Understanding of cloud computing such as the advantages/disadvantages of IaaS, PaaS, SaaS • Evaluate the suitability of cloud solutions against the business needs	• Understanding of cloud computing such as the advantages/disadvantages of IaaS, PaaS, SaaS • Track development of emerging technologies in the industry and collate information for technology implementation • Perform cost-benefit analysis and evaluation of the relevance, viability, sustainability and potential value-add of emerging technologies to the business and identify and select compatible emerging technologies • Review emerging technology, evaluate and determine relevance of emerging technologies to the organisation • Lead analysis of emerging technologies and drive implementation of industry specific technologies for organisational effectiveness and competitiveness	

Integrated Digital Delivery	Integrated Digital Delivery	• Influence the adoption of Integrated Digital Delivery (IDD) technologies to manage projects and building life-cycle efficiently • Lead the adoption of Integrated Digital Delivery (IDD) technologies to manage projects and building life-cycle efficiently	• Assess the viability of the adoption of Integrated Digital Delivery (IDD) technologies to manage projects and building life-cycle efficiently • Implement Integrated Digital Delivery (IDD) technologies to manage projects and building life-cycle efficiently	• Support Integrated Digital Delivery (IDD) implementation
Application Integration	Middleware Programming	• Establish a business case for application integration and introduce new middleware tools and methodologies to enable both intra- and inter-enterprise application integration	• Integrate data and functions across application programs, and perform follow up tests to verify proper functioning • Oversee end-to-end process of application integration, determining suitable middleware and testing procedures and resolving issues that arise • System Integration and Migration • System Analysis and Design	
Cybersecurity	Cybersecurity	• Establish cybersecurity risk management strategies, policies	• Develop awareness on cybersecurity threats and risks within the industry, and apply appropriate risk management actions to protect the	• Do and Don't for Cybersecurity

		and procedures to counter cybersecurity threats and risks as well as respond to cybersecurity breaches	organisation and respond to cybersecurity breaches • Develop appropriate cybersecurity procedures and practices to ensure protection and response to identified cybersecurity breaches, as well as guide their implementation within the organisation	

Table 6. Technical Skills and Competencies (TSCs) matched to the respective groups

Step 3: Find suitable methods for users to develop the skillsets

In building up digital capabilities, organisation should recognise that there are multiple approaches aside from just classroom training. Organisation could leverage on more experienced staff to provide coaching to less experience staff. This approach will help to contextualise the scope of the training to the organisation's needs and be able to address the set of problems and challenges within the organisation more accurately.

Recognising that the pace of learning differs from individual to individual, organisation could also consider setting aside an hour each week to hold clinic sessions that are hosted by Subject Matter Experts to help and coach.

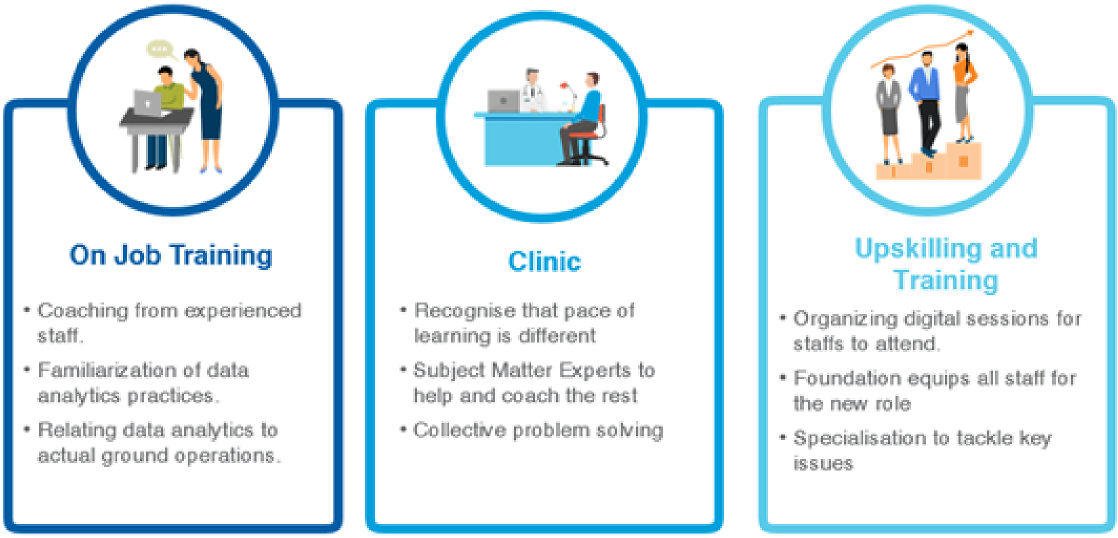

Figure 16. Multiple training approaches for individuals in an organisation

Step 4: Practice, Refine and Sharpen

As with every newly acquired skillsets, it is essential that users continue to practice, refine, and sharpen the skills to build deep skills and knowledge in key focus areas. Users will move from a Basic level to an Intermediate level and to an Advance level where they will be recognised as a Subject Matter Expert (SME). Through this journey, the SME will then be able to help and coach less experience staff and uplift the organisation's digital capabilities in the FM sector.

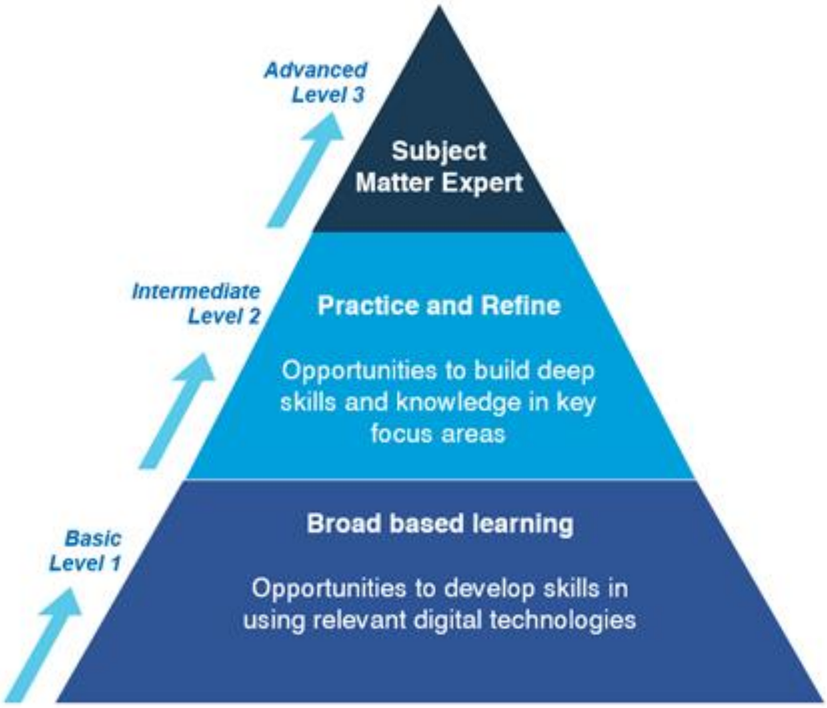

Figure 17. 3 levels to uplift digital capabilities in the organisation

Chapter 6. Conclusion

This Guide to Smart FM aims to help Building Owners and FM Managers articulate and realise their desired Smart FM outcomes. It has shared on core principles of the Smart FM Framework and provided a 5-Step SMART Process to help the Building Owners and FM Managers in identifying their business objectives, Smart FM outcomes and prioritising key FM services for the adoption of suitable technology solutions. ***Appendix E: Decision Template for 5-Step SMART Process*** has been included to guide Building Owners and FM Managers through this process as they embark upon their Smart FM transformation journey.

This Guide has been enhanced to provide more guidance on Type 3 Smart FM processes, technologies, and digital skillsets. Vendors/sub-contractors, FMCs, and Building Owners may use the Digitalisation Maturity Map to understand their roles and the interaction between these 3 digital entities to cohesively delivers the benefits of FM integration and aggregation. FMCs or Building Owners may also want to set up a Common Data Environment (CDE) for FM to better manage data and gain insights across FM systems/services that empower decision-making process. As we redesign processes, adopt new technologies and learn new digital skills, it is important to ***begin with the end in mind***, and be guided by clear objectives and desired outcomes in our Smart FM journey.

With this enhanced Guide, the FMIC and the Integrated Smart FM Taskforce hope to encourage the FM industry to develop stronger partnerships and strategic alliance to reduce fragmentation and to redesign FM processes and jobs & skills while reaping the desired outcome of the FM industry transformation.

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Appendix A: List of Smart FM Point Solutions

The market for Smart FM technology solutions is maturing and the product range is comprehensive and ever-growing. Examples of smart FM solutions include IoT, data analytics and artificial intelligence, to pre-empt fault, optimise energy and manpower use, or enhance occupants' experience and the FM Team's ability to measure and meet desired outcomes.

To lower the technical hurdle and cost barrier, most FMCs or Service/ Solution Providers offer a cloud-hosted option on a subscription basis.

The cost of Smart FM can be significantly reduced if the necessary supporting infrastructure was designed for "smart" from day one within the base building systems. Nevertheless, it is still possible to progressively build up the supporting infrastructure for Smart FM. Building Owners and FM Managers can explore various point solutions such as those listed below to address specific FM pain points related to infrastructure and common services.

The list is non-exhaustive; omitted are commercial systems such as retail signage, payment systems; and familiar technologies like the building automation system (BAS) and non-routine specialist activities like façade inspection.

<u>M&E Services</u>

1. Condition Monitoring of Chillers, Pumps, Lifts etc
2. Energy Performance Contract
3. Air-con as a Service
4. Fault Detection and Diagnostic

<u>Security</u>

5. Video Surveillance and Analytics
6. Visitor Management
7. Location Tracking

Environment Services

8. Smart Toilet System
9. Rodent Management System
10. Robotic Floor Cleaner

Converged Services

11. Connected Light System
12. Room and Space Management, Hot-desk
13. Emerging Services
14. Demand Response Program
15. Advanced Robot for Façade Cleaning

Appendix B: Facilities Management Consortium Operation & Technology Roadmap (COTR)

To build a future-ready FM sector as part of the Built Environment Cluster – Real Estate Industry Transformation Map (ITM), the Singapore International Facility Management Association (SIFMA) worked with the Agency for Science, Technology and Research (A*STAR), supported by the Building and Construction Authority (BCA) and Info-communications Media Development Authority (IMDA), to develop a Consortium Operation and Technology Roadmap (COTR) for the sector.

Aligned to the ITM, the COTR aims to outline the general trends and direction of the FM sector, map out technology solutions and prioritise them according to the needs of the sector from 2018 to 2027. The COTR serves as a useful reference to translate some of the identified areas, from short to long term, into actionable outcomes for the sector.

More than 100 people from 50 organisations across the industry, academia, and government agencies participated in the 3 facilitated workshops and mapped out over 50 technology solutions under the COTR.

The COTR report is expected to be released in October 2019, and more information can be found in the SIFMA website at https://www.wgs1.net/ifma-sg/.

Appendix C: Case Studies

C.1 Intelligent Building Platform (IBP) at CapitaLand

CapitaLand Group (CapitaLand) is one of Asia's largest diversified real estate groups. With a presence across more than 250 cities in over 30 countries, CapitaLand focuses on Singapore and China as its core markets, while it continues to expand in markets such as India, Vietnam, Australia, Europe and the USA. Headquartered in Singapore, CapitaLand's portfolio spans across diversified real estate classes which includes commercial, retail; business park, industrial and logistics; integrated development, urban development; as well as lodging and residential.

Over the past 3-4 years, with the proliferation of (Internet of Things) IoT and innovations around connected ecosystem of sensors/ control systems/ networking/ cloud computing/ data analytics and artificial intelligence (AI), CapitaLand has been an early adopter of such technology and in the forefront of driving technology-led business innovation in the built environment across the facility lifecycle.

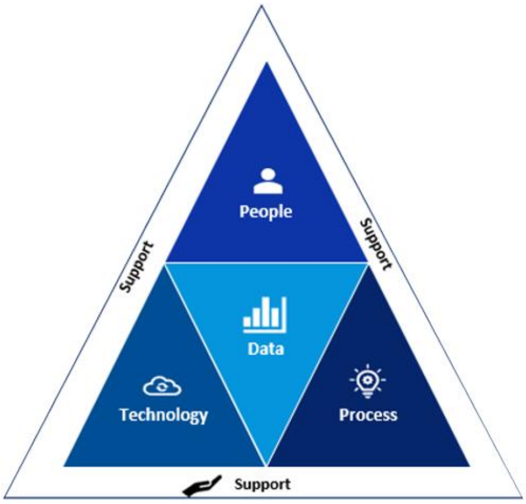


Figure 18. Triangulation of People-Process-Technology

As an integral part of the BCA taskforce, CapitaLand has taken the leadership and embarked on the journey of next generation facility operations and management with triangulation of People-Process-Technology.

Driven by data at the core of its operation powered with necessary support from internal stakeholders as well as its partner ecosystem, CapitaLand has been committed to this journey and successfully implemented its future focused platform named **"Intelligent Building Platform"** hereinafter called as **IBP**. Over the last few months and years, IBP has been established as the ***facility operating system*** at CapitaLand and has shown encouraging signs of transformation of conventional facility operations to intelligent and Smart FM in multiple dimensions.

Below are to name a few:

- Visibility of asset performance across portfolio and its management
- KPI tracking and associated improvement actions
- Predictive and continuous maintenance regime from an event driven maintenance
- Smart Assignments
- Facility Workforce productivity tracking and improvement
- Occupant and customer experience/ touchpoints

Powered by cloud technology and an unified data platform for [data] visualization, IBP is ubiquitous in delivering the Smart Facility operations at 42 facilities in Singapore. It essentially breaks the notion of centralized operations centre and ties the ecosystem nodes of facility workforce and service partners on an interconnected mesh.

The sections below outline how the BCA 5-step **SMART** framework was put into practice while deploying and operationalizing **IBP**, the operating system for digitally transformed next generation facility management.

Step 1: <u>S</u>et Business Objectives and Outcomes

The Coverage:

The impact of a digital transformation is more effective when deployed at a larger scale. At CapitaLand the decision was to implement in

Singapore - 42 properties in Phase-1 across Business Park, Commercial, Retail, and Integrated developments.

Singapore Landscape – Phase 1 Deployment: 42 buildings

BMS Provider	Install Base (buildings)
Johnson Controls	13
Trane	06
Azbil	05
Honeywell	05
Siemens	04
M&V	02
Quantum	02
BMS Engineering	02
Carrier	01
PRIMUSTECH	01
Evergreen	01
TOTAL	42

BMS Protocols	Install Base (buildings)
BACnet IP	17
OPC DA (Savic net)	06
OCP DA (EBI)	05
OPC DA (KONE OPC)	05
OPC Lift	04
MODbus	05
TOTAL	42

Figure 19. CapitaLand's Intelligent Building Platform implemented in 42 buildings

With business objective of Smart FM and BCA framework as guidepost, CapitaLand defined the "Why", "What" and "How" and created the guiding principle.

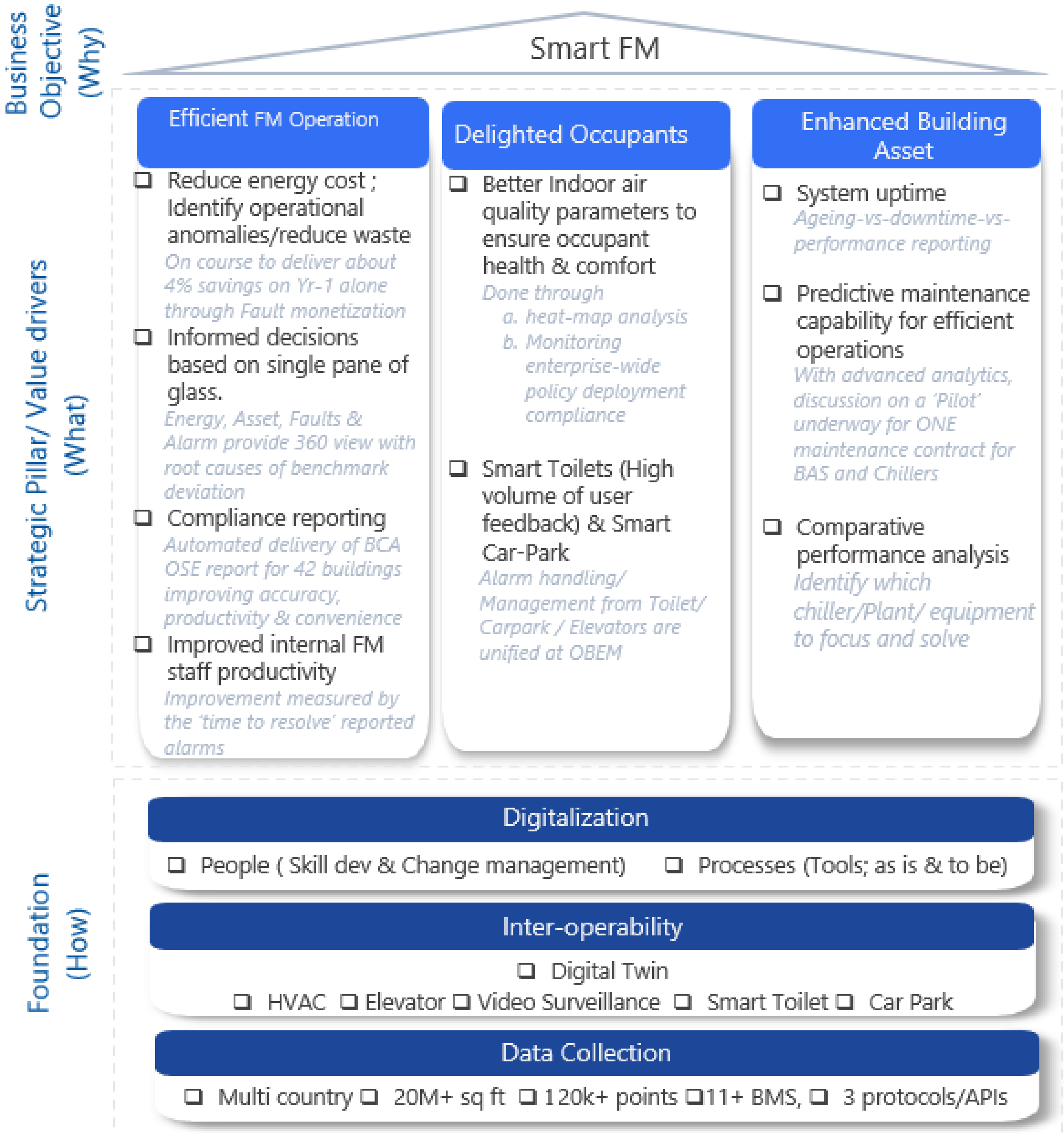


Figure 20. CapitaLand's guiding principle on Smart FM

Step 2: Map Out Smart FM Solutions as Enablers

The success of Step 1 is as good as how good the vehicle of delivery is. Choosing a right technology platform that is sustainable, future-proof and have a credible track record depends on the software architecture of the data platform for business analytics.

Below is a list of generic checkpoints used in the process of technology selections:

- Data Ingestion methodology and support: Time series events from disparate sources

- Open API's access for co-existence of ecosystem of SME providers

- Distributed architecture having microservices implementation for autonomously distributed computing at the edge level

- Big Data storage and data processing system

- On the analytics side, the data platform has to perform
    - Rule-based (mathematical expressions based on "if", "then else" and simple equations analytic decision approach
    - Ability to carry out statistical analysis
    - Performed reinforced or deep learning. Based on statistical data, the system recognizes the pattern based on historical data and takes appropriate action automatically (AI)
    - Able to manage complicated workflows

- Business Apps (Business Intelligence): Business Intelligence (BI) in an IoT environment involves enabling easy creation and access to dashboards and analytics across multiple data sources and types for less technical users. Enabling user to conduct their own analytics and create dashboards/reports; and the output of these to be delivered through multiple channels around desktop, mobile, and web.

- Capability for
    - Energy Management
    - Alarm Management
    - Asset Equipment Management
    - Workflow Management

- Flexibility of data mining and reporting

The Implementation:

Below is an overview of the deployed digital platform as well as the associated apps and modules.

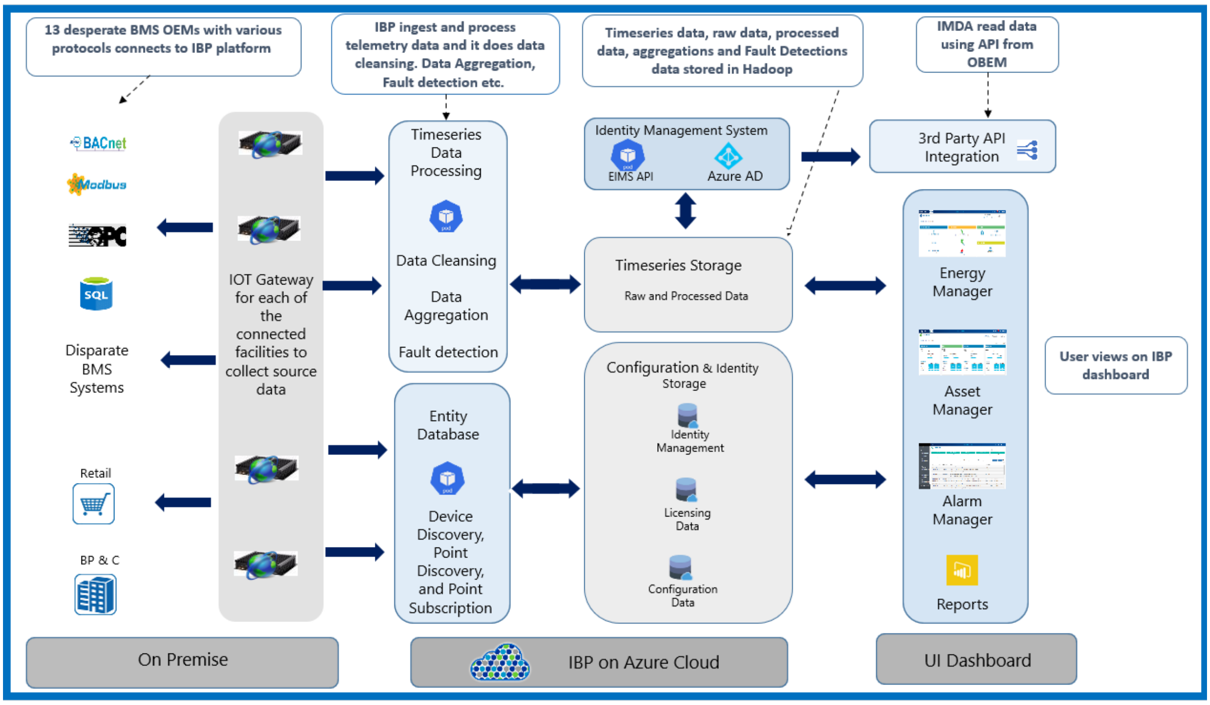


Figure 21. Digital platform and the associated apps and modules

Components of The IBP Digital Platform

Following are the components and capabilities of the deployed digital platform.

1. Data ingestion: The proposed digital platform must address how it will ingest and refresh data from OT sources such as the HVAC equipment, security systems, and other operational data, and from external data sources such as

weather. The focus is to support both structured and unstructured data, and how to build and deploy ingestions in a repeatable and reliable manner that can be monitored for timeliness and quality.

2. Data abstraction, entity management, and data virtualization: The deployed solution included a facility for data cleaning, matching, integration and data virtualization. Facility Management Staff can use the platform to get a unified view of all buildings that they have access to view.

3. Metadata management, data catalog, and data lineage: IBP included a catalog of data included in the platform and the metadata for that data, the lineage of the data, and a search over the data itself and the metadata. The platform included capabilities to support a master data management process tailored for the smart environment, along with supporting capabilities for data governance.

4. Device registry and asset tracking: IBP has the ability to provide a registry for devices and assets like IoT devices, Location of Things (LoT) devices tracking movable assets or other fixed devices. The registry provides an identifier for each device, and metadata about how the device can be authenticated, as well as the health and operational status of the device. The platform supports the definition of geospatial regions that can be used for geofencing and other geospatial analytics.

5. Intelligent messaging: IBP includes a messaging system for components, services and devices to communicate. The messaging system uses open protocols to maximize its ability to integrate with other systems and integrates with bridges and protocol gateways as necessary, so applications can have seamless access to all devices without needing multiple integrations per application.

6. Data analytics and machine learning: The platform included analytic capabilities for reporting, visualization and dashboarding, and the development of other KPIs. The machine learning techniques provide more sophisticated analytics for predictive maintenance, anomaly detection, and other classification problems.

7. Identify management: The identity management and access control services provided an integration layer with any existing systems already in place. The security team, risk management team, legal, and other stakeholders vetted the developed RFP to ensure that all compliance requirements are met. All platform services include support for auditability and traceability.

8. Cyber security protection: The platform has the capability to protect against cyber-attacks and intrusions and incorporated security approach to restrict intrusion at different levels of integration and how data security is maintained.

9. Managing compliance and performance of connected assets: The platform also included capabilities to monitor the current state of connected assets and integrate the real-time state with maintenance records of the assets and analytics against the device, to proactively and efficiently ensure that all devices and assets always operating within specifications, as well as to provide all necessary documentation to meet audits and compliance processes.

10. Reporting: IBP has flexible reporting module that allows the users to have both canned and user definable BI reports without additional software development or coding. This is critical given the evolving needs of the facility.

Step 3: Adopt Suitable Implementation Model

For IBP, Software-as-a-Service subscribed over cloud was chosen as the preferred model of implementation. The decision was primarily guided by the need to

- Negate the cost associated with maintaining dedicated IT infrastructure
- Ensure high availability
- Scale the application over time with a growing portfolio of buildings
- Future proof the system to avoid risk of obsolescence
- Align OPEX with performance

Implementation Framework

Working together with the implementation partner, CapitaLand implemented a 4-stage framework for the technology deployment and subsequent adoption and value capture.

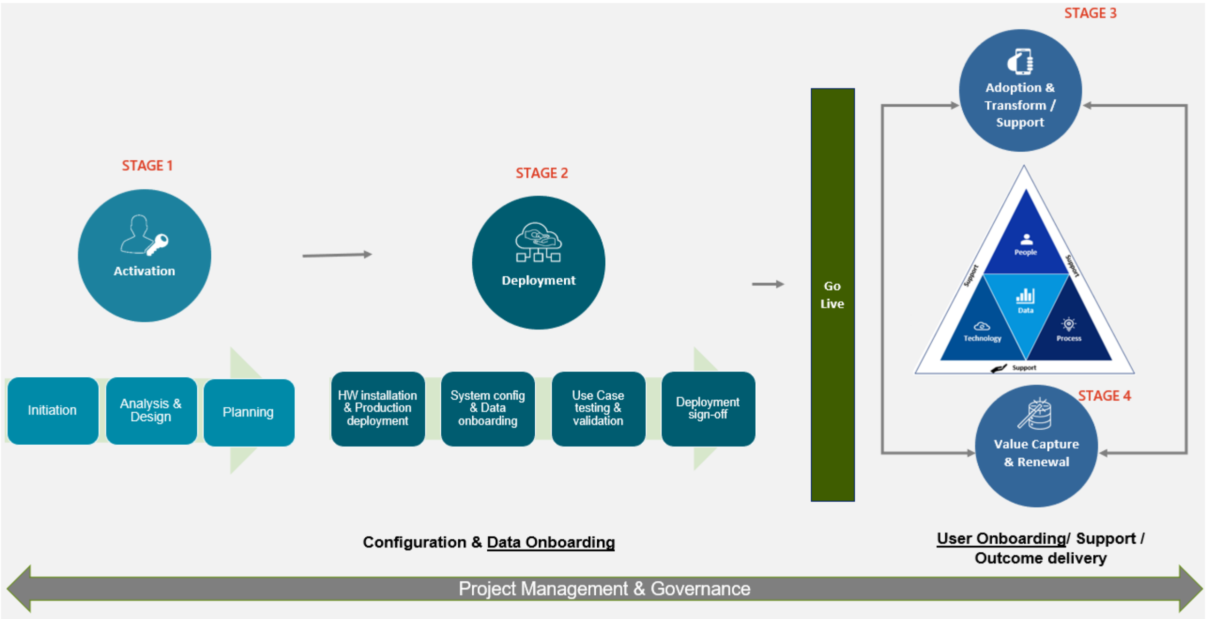


Figure 22. 4-stage framework for technology deployment and subsequent adoption and value capture

Stage 1: Activation

This stage was to create technology, execute, support, and adopt the roadmap to realize the digitalisation vision of CapitaLand.

Initiation:

During this phase. CapitaLand and the vendor go through each requirement with the stakeholders. Introduce different stakeholders and understand their requirements.

Analysis and Design:

During the design phase, the team (CapitaLand & vendor partner) will reach agreement on a shared vision for the work stream and scope that will be required to make that vision a reality.

Planning:

During the planning phase, the team will develop a detailed plan for the work stream that includes a list of activities that are to be completed, and the work stream schedule. In addition, finalization of technical decisions should be achieved. For example: Vendor API access etc.

Stage 2: Deployment

This stage is to install the requisite gateways and routers, perform integrations with source data, Provision the Software subscription in cloud, ingest data, stabilize, and perform data validation.

Hardware Installation & Production deployment

Hardware (IoT gateways) were installed, source data integrated, and vendor DevOps provisioned applicable licenses and features per entitlement.

System Configuration & Data onboarding

The building, floors, spaces, equipment, and meters are configured, and all data points are mapped. Respective analytics triggered. Reports configured.

Use Case Testing and Validation

Validates that all delivery obligations, journey maps / use cases as per “Solution Document” are demonstrated to user groups and sign-off obtained.

Deployment Sign-off

Necessary user training provided, configurations and network setting documented and signed-off facility-by-facility.

Stage 3: Adoption, Transformation, and Support

Adoption & Transformation

At this stage, usage is monitored to pre-empt adoption impediments and provide guidance to continued/periodic training, support the user beyond the software features and ensure that people and processes are aligned for digital transformation.

Support

The vendor partner provided routine monitoring, and maintenance for the application, and where necessary communicate bug fixes, enhancement, new features upgrades/updates to customers. It also provided applicable level support for delivering and implementing updates/upgrades; presented upcoming features and product roadmap and align customer's expectations.

Stage 4: Value Capture and Renewal

This works in parallel with Stage 3. The 'value' through a set of actionable recommendations is iteratively measured and calibrated to derive the intended outcome from the system.

The journey map below illustrates how processes are developed/tweaked, and users are trained to derive the maximum outcome from the digital transformation journey.

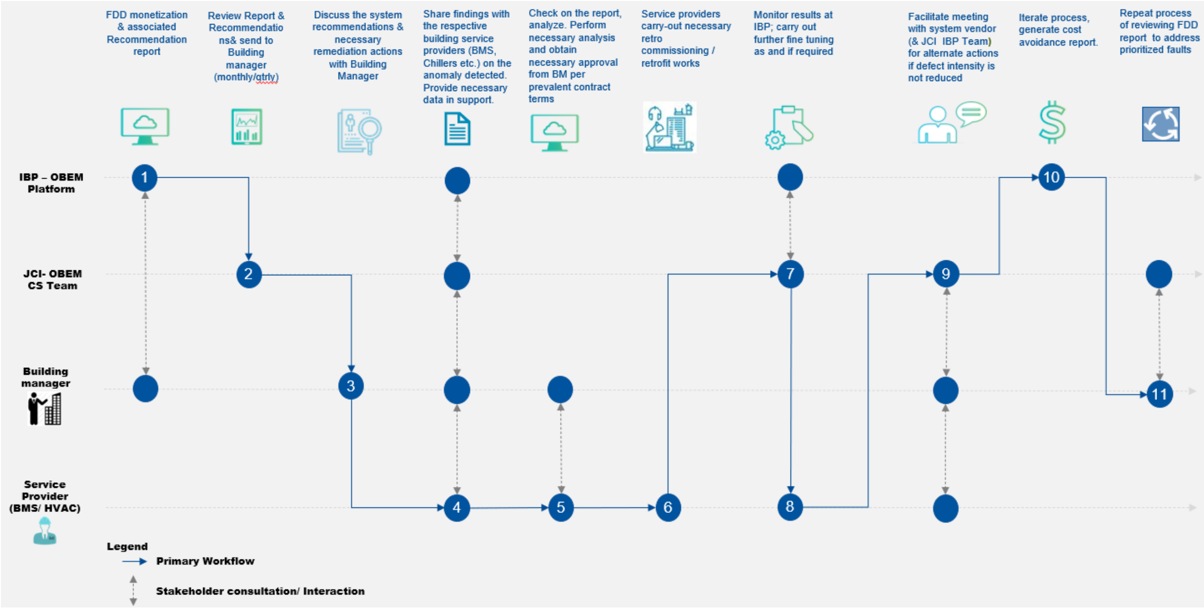


Figure 23. Processes illustrated by CapitaLand's journey map

Team Health:

Besides the implementation approach and framework, defining the key stakeholders with clear identification of the roles and their responsibilities is critical to success.

The following steps were followed while deploying IBP across the 42 facilities in Singapore.

1. Establishing 'One' organization structure to accentuate the partnership relation between the vendor and CapitaLand.

2. Have a clear RACI (Responsible, Accountable, Consulted, and Informed) matrix to enable clarity of roles and contributions of everyone towards the success of the implementations.

			Vendor Partner						CapitaLand				
	Phases	Tasks	Customer Success Manager	Product Support (L2/L3)	Account Manager	Delivery	Solution Design	DevOps & IT	Program Director	Facility SPOC	Control Group	IT	Other Users
Stage-1 Activation	Know your customer (KYC)	Contract Details-Costing & Timelines	Venki (A/R)		Connie (R)	R	I	I					
		Customer Org & Key stakeholder mapping											
		JCI offering mapping / Key stakeholder											
		Opportunity landscape											
		Customer vision & Value driver											
	Project Kick-off	Customer vision and Value drivers	A		R	R	R	R	A/R	R	R	I	
		As-is process mapping											
		To be' state mapping; to be process definition/ Journey map based on persona's and roles											
		Expected Timeline											
		Org structure JCI as well as customer for the project											
	Mobilize	Resource deployment	A/R	I	I	R	R	R					
		Know the site and facilities											
		Assess deployment pre-requisites per solution											
	Customer Success Plan (CSP)	Solution Document	A		C	R	R	C					
		Prerequisites and its readiness											
		Customer stakeholders engagement plan											
		Project Plan											
		Pre-mortem / Risk Assessment											
		Governance Process- Communication plan and escalation Matrix											
		Communication plan - Progress reporting											
	CSP signoff	Customer training and workshop with "control group" on the 'Digital journey	A/R		I	R	R	I	A/R	R	R	R	
		Seek to understand; Drive alignment											

Responsible Accountable Consulted Informed

Table 7. Sample RACI

Step 4: <u>Review procurement contract</u>

While embarking on the digitalization journey, **the first phase** was to deploy a digital platform and associated application ecosystem. With the Intelligent Building Platform (IBP), CapitaLand started with the end of outcome-based contracting in mind. The IBP contract was crafted with multiple considerations.

1. Outcome definition as part of contract

Essentially the outcomes were defined in line with the stated Smart FM goals of (i) Energy Savings, (ii) Better Asset Performance, (iii) Increased Productivity of FM workforce through digitally enabled workflows, and finally, (iv) Customer Satisfaction through faster response and remediation to alarms and incidents. CapitaLand outlined these expectations

a. The targeted energy (kWh) savings number as energy cost avoidance due to implementation of advanced fault detection and diagnostics. We ensured that the savings number is realized within the first year so that the same can be carried forward for subsequent years of operations. This was done through automated identification of Energy Conservation Measures (ECMs).

b. Utilizing IBP to achieve definitive productivity savings with an automated Alarm Activation and Tracking mechanism, to include date and time of active fault, type of fault, respond and rectification time.

c. The use of an automated system enables the Customer to move from a traditional way of managing BMS alarms and User notification.

d. Called for a framework where CapitaLand and IBP provider can work together to map the As-Is and To-Be Process to better understand the productivity savings as.

2. Defining the as is and post digitalization of FM workflows

A set of use cases and corresponding workflows were defined and made as a part of the contract itself under the "People-Process-Technology" triangulation as outlined in the introduction and Step 3.

Below is an example of Alarm Handling Workflow under the contract:

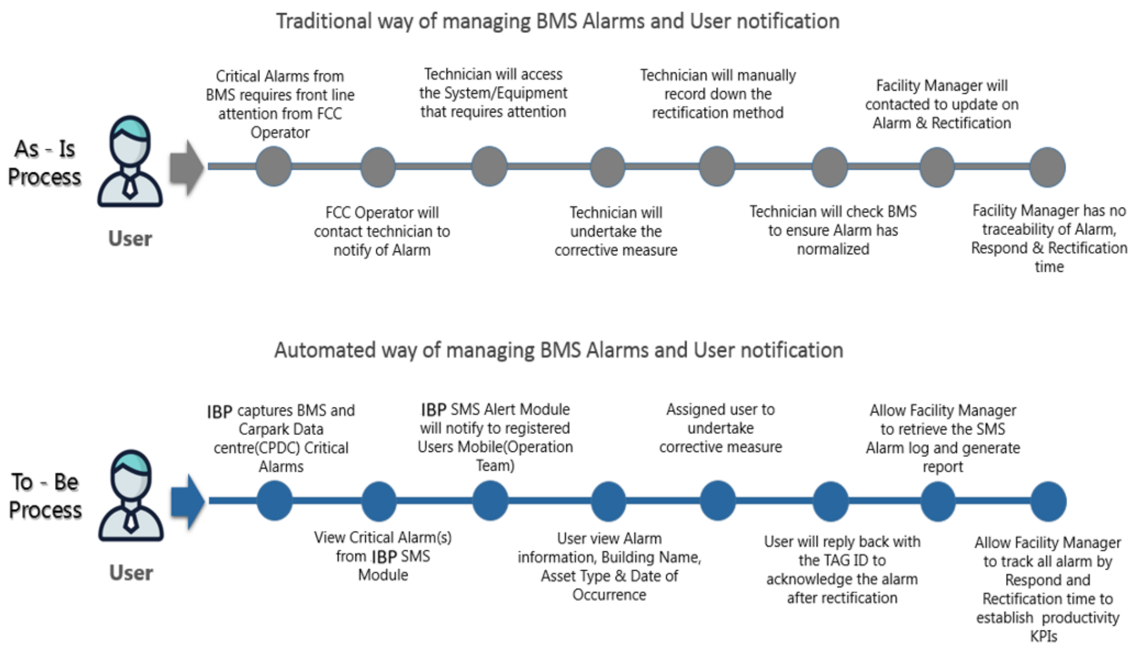


Figure 24. Traditional and automated way of managing BMS Alarms and User notification

3. Multi-year contract on a S-a-a-S model enabled accountability of delivery while optimizing cost

Though the IBP project was done on a OPEX model, the contract was structured into two distinct phases

1. Deployment
   Under this phase, data from 42 buildings were ingested and onboarded. Analytics applied to get the intended outcome from the system

2. Post GO LIVE User adoption and platform maintenance services.
   Data Sanity as well as subsequent user adoption in implementing the analytical recommendations from the systems hold the key in any success of any digital transformation. A special care has been taken to provide for required digital competency in helping the building managers in the change management process.

4. Service Level Agreements to ensure best-in-class support

CapitaLand defined the following model to ensure adequate support for the IBP solution from the Vendor Partner's support team. The roles and responsibilities, as well as the Service Level Agreements (SLA) were finalized on mutually agreed terms.

Level 1 Support - The Level 1 Support would be the first point of contact to Vendor Partner's Service Hotline Call Centre, who will assist in assigning the issue/ fault to the Service Team (Local Branch Team) for Level 2 Support.

Level 2 Support -Vendor Partner's Service Team covers the following:

- User and Admin Portal Help
- IoT Gateway issue
- Data collector issue

Level 3 Support – Vendor Partner's Technical Support Team covers the following:

- Environment support
- Configuration (users, spaces, points, etc.) and Configuration Changes
- Integration Support and Troubleshooting (Local Branch Team)

Service Level Agreement (SLA)

Response times are applicable for all tickets and calls that are initiated and escalated by CapitaLand's team. Once the inputs are acknowledged by the support team and based on severity level, following SLA are proposed. The response and SLA term will be based on the severity of the error as defined in the table below. The vendor will use commercially reasonable efforts to resolve each error (i.e., any material failure of the Services to perform as contemplated under the SLA) and will provide periodic updates on the status of the error at the frequency outlined in the table below. The response times and customer update frequency outlined below are only applicable to the production instances of the services.

Having successfully implemented the above, in the second phase, CapitaLand is evaluating how to migrate the standard building services maintenance contracts to ones that are data and condition driven. The participating vendor partner are working with CapitaLand actively for an expert dispatch of their maintenance/service crew. This is CapitaLand's first step to move from a scheduled/event driven maintenance regime to one that is digitally driven, predictive and as-needed.

Step 5: Track outcomes and review continuous improvement

Below are some examples of the outcome realized so far from IBP:

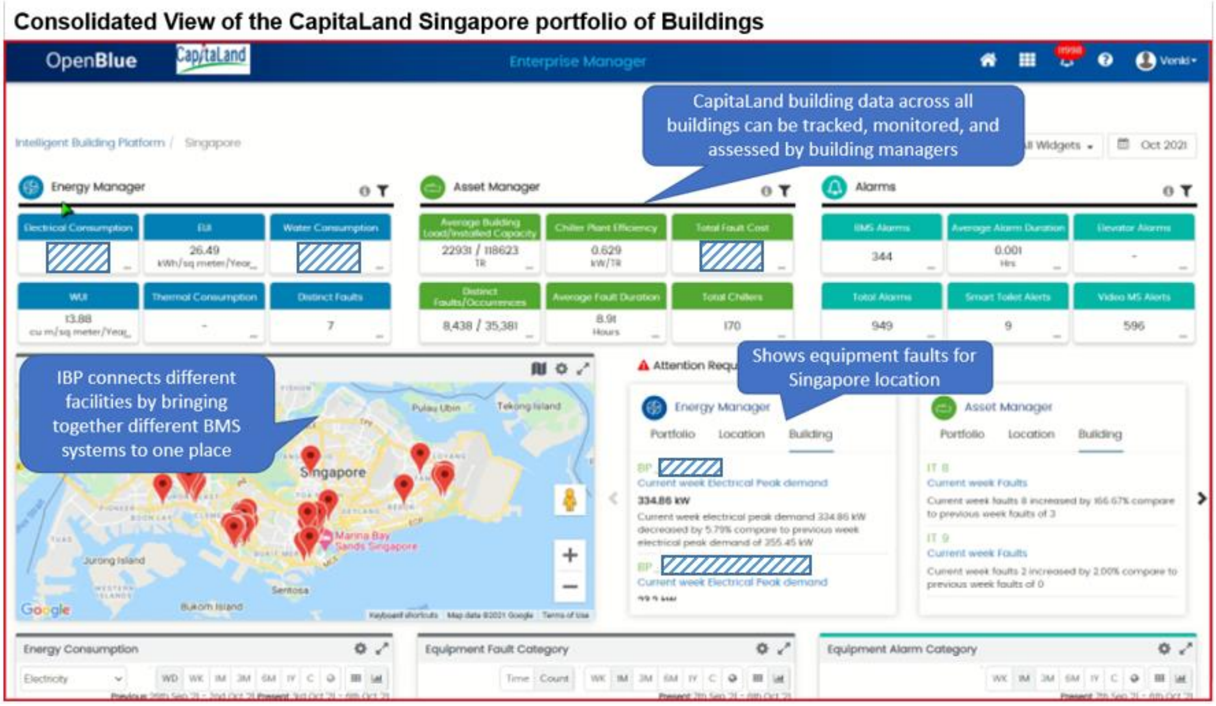


Figure 25. CapitaLand's Intelligent Building Platform and its data

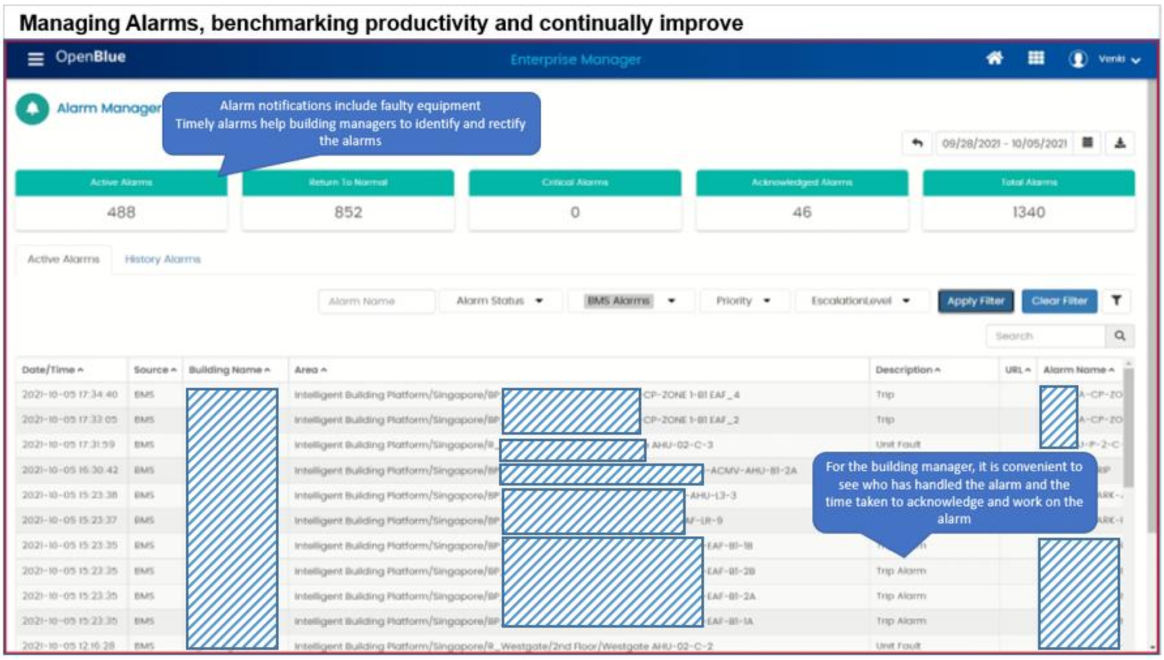


Figure 26. Alarm Manager

Asset Ageing and KPI comparison

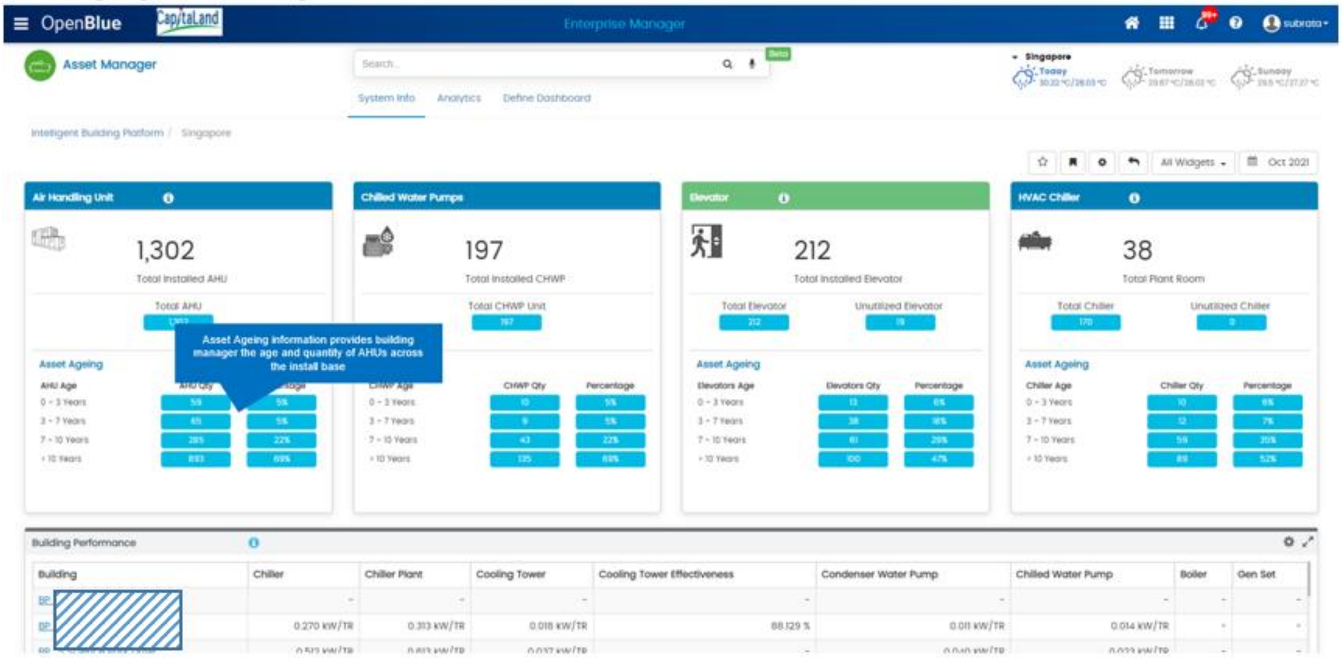


Figure 27. Asset Manager

Fault Analysis by Fault Count, Category, and duration enabling prioritization of required actions

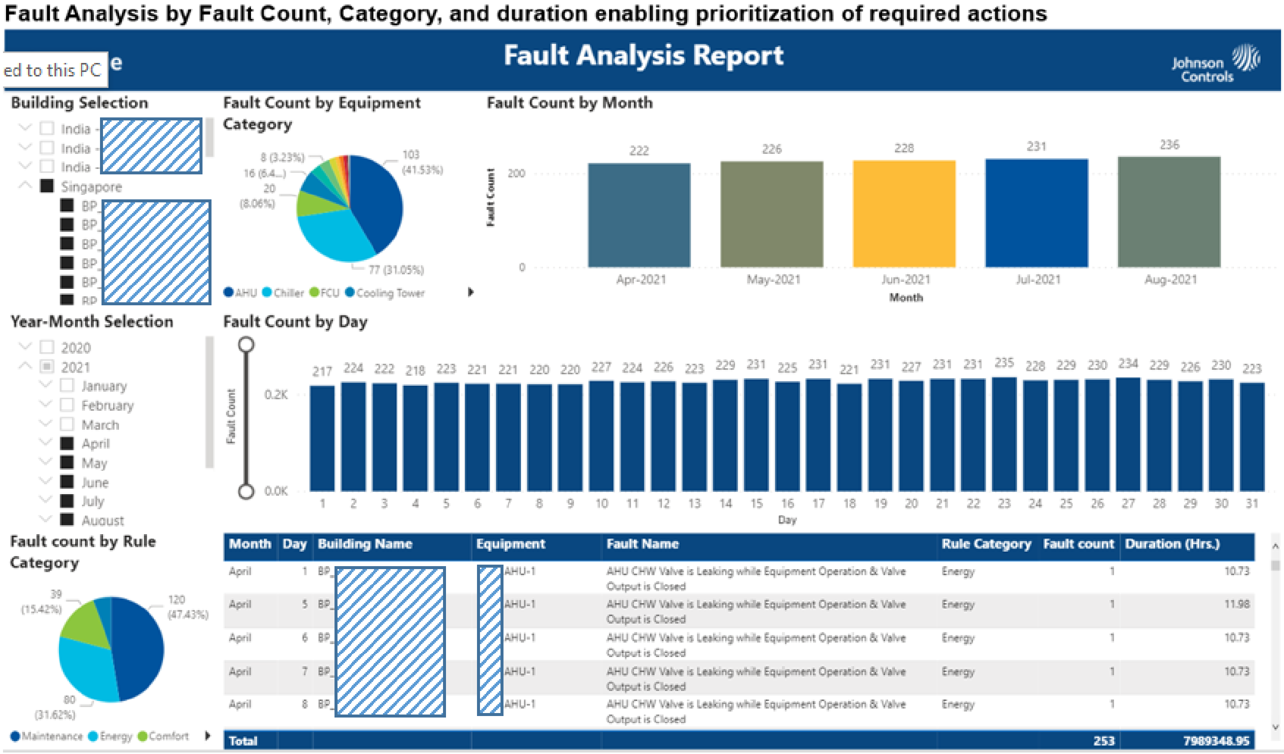


Figure 28. Fault Analysis Report

Figure 29. AHU Return Air Temperature Anomaly Analysis

Lessons Learnt

While the digitization journey is successful so far, below are a few points that prospective adopters of similar platform should consider

1. Data Ingestion to Digital platform – inform all stakeholders when there are any changes at the source systems

   The disparate legacy BMS systems' data points need mapping at the digital platform. In the absence of a common data model at the source systems, these activities are often manually carried out with intensive effort. Any change in the BMS system components / upgrades may potentially impact the data mapping process resulting in duplication of effort and cost. Often, advance, and proactive communication involving relevant stakeholders could mitigate such risks.

2. Engagement and active participation of users in the development and implementation process.

   Platform implementation is comparatively easier given that the BMS technology eco-system is quite mature. In this respect, user acceptance and associated change management, training and process/workflow fine tuning consumed most of the time. An early engagement could work as a great catalyst in overall adoption and hence quicker 'Value' realization of the digital platform like IBP.

3. Move up the maturity curve. Reduce human intervention in the process.

   Wherever applicable and possible, aim for autonomous actuation of the recommendations from the analytic platform without the need of human intervention. This consideration at the design stage itself will accelerate the 'Value Capture' process.

The deployed digital platform has given the value insight and ease of access to the asset data, which allow the facility team to better manage them.

C.2 Lingjack Digital Smart Fire Safety and Emergency Platform

Overview

Lingjack Digital was formally created in 2021 to create and provide IoT (Internet-Of-Things) solutions that solve Customers real-life problems in an innovative, non-intrusive manner. At the same time, creating real value to customers/stakeholders to maximise operational and cost efficiency, increase productivity, downtime and manpower.

Lingjack Digital's Smart Monitoring and Control Platform was designed and developed to provide a one-stop, customisable platform for 24/7 electronic monitoring, control, and alerts for different domains such as Environmental, Water, Energy utilisation, Flood Detection, Water Pump, Fire Safety and Emergency Monitoring and Control etc.

Specifically, the Lingjack Smart Fire Safety and Emergency Platform was developed to manage fire safety products and assets within an easy-to-use workflow. The workflow consists of 5 simple steps: (1) 24/7 active monitoring, (2) Remote automated testing, (3) Non-compliance detection and notifications, (4) Corrective Action & Resolution, (5) Service Records/Reports.

The Smart Fire Safety and Emergency Platform was deployed at 2 operational sites to electronically monitor and manage the operational status fire extinguishers and exit lights.

Step 1: Set Business Objectives and Outcomes

The Singapore Fire Safety Standards (SS 578 and SS 563) requires fire extinguishers, exit lights and emergency lights to be inspected monthly. On the ground, building owners and Facilities Managers face the following challenges:

a. Low productivity: The time consuming and repetitive inspections are carried out by FM staff
b. Manpower constraints: Rising manpower cost and manpower shortage
c. Risk of equipment failure in-between monthly inspections

To address the challenges above on fire safety, Lingjack Digital has identified the following business objectives and FM outcomes to focus on:

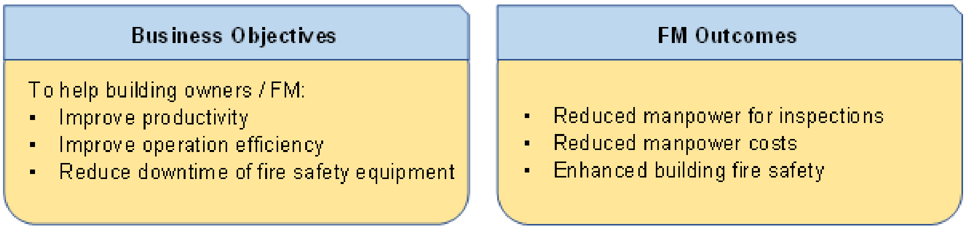


Figure 30. Identified business objectives and FM outcomes to address challenges on fire safety

Step 2: Map Out Smart FM solutions as Enablers

To achieve the business objectives and outcomes, the SMART Fire Safety and Emergency Platform was developed to address these challenges. The smart solutions on this platform are mapped out below.

Type	Scope	Building Level FM Services
Type 1	Digitalise Assets	Fire Safety Asset Tracking and Location Tagging  Fire Extinguishers  Exit Signs  Emergency Lights
	Digital Workflow Automation	Automated Workflow • Active 24/7 operational status and fault/non-compliance monitoring, alerts and management. • Regulatory adhoc and routine testing • Events Logging • Fire Product Asset Management • Service Panel for Service Inspection, Incident Logging, Tracking and Reports
Type 2	Optimisation within System	
Type 3	Integration Across Systems	Bridging APIs could be developed in future for integration with other smart systems

Table 8. Lingjack's Smart FM Framework

SMART Fire Safety and Emergency Platform (Type 1)

The SMART Fire Safety and Emergency Platform is an IOT-based platform that reinforces regulatory code compliance and increases the operational readiness in fire safety products. This is achieved through non-intrusive, distributed, electronics monitoring. The platform simplifies and automate the management of fire safety products through 5 simple stages illustrated below.

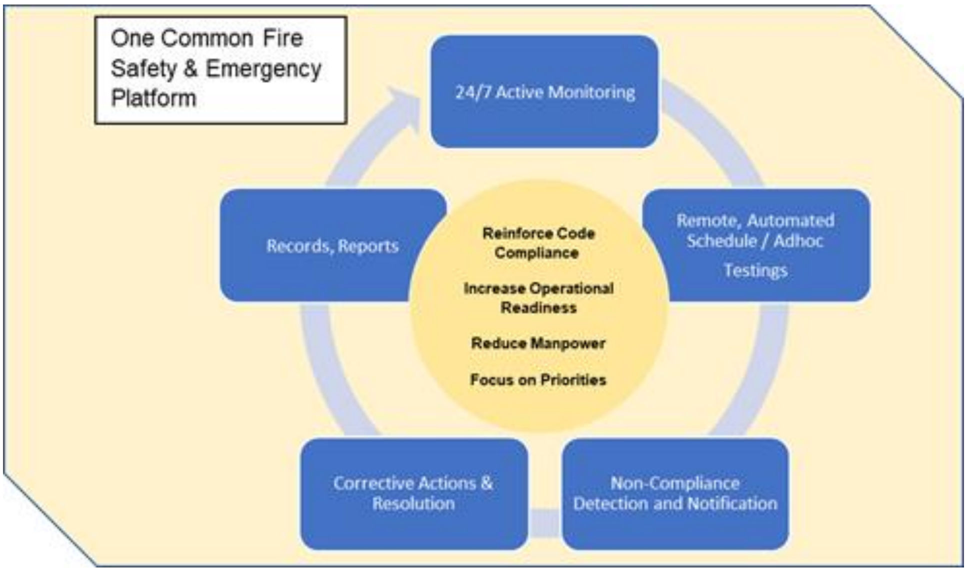


Figure 31. Automated Workflow of Smart Fire Safety and Emergency Platform

The platform could integrate with third-party service agencies (eg. yearly maintenance) into this maintenance eco-system to provide a total management and safety preparedness status of the buildings.

The SMART Fire Safety and Emergency Platform uses Cloud and IoT technologies. Wireless Smart Nodes are deployed to monitor different safety aspects of fire safety products. (e.g., fire extinguisher for leakage, missing, access obstruction, exit light for failed lamps or drained battery). Data are sent wirelessly on a secure mesh network and push to the Cloud for analysis and decision-making. Users can view, monitor, and control the fire safety products 24/7 remotely on the browser or mobile app.

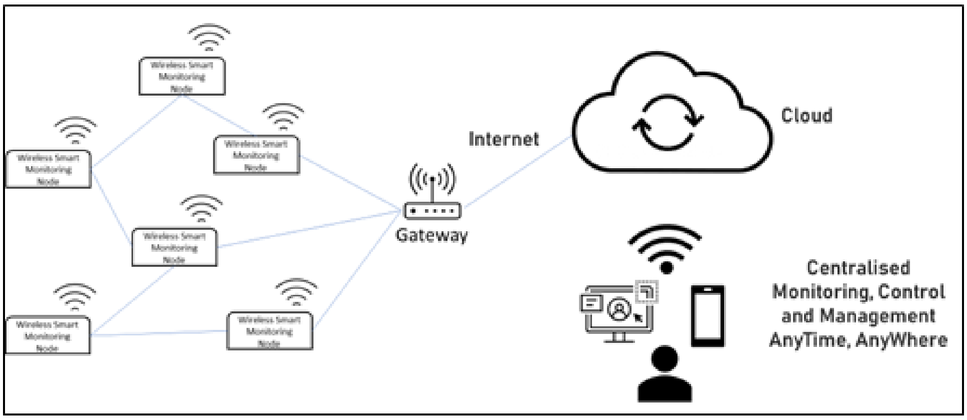


Figure 32. A Cloud and IOT-based Smart Fire Safety and Emergency Platform

Other Smart Nodes (eg. fire door, pump monitoring, energy usage etc) could be easily added onto the deployed infrastructure by having them connected to the same wireless network.

Figure 33. Smart Nodes connected to the platform

<u>24/7 monitoring of fire safety systems</u>

Through the Smart Fire Safety and Emergency Platform, the facilities manager and his maintenance team now have visibility of the live fire safety readiness of the fire extinguishers, exit lights and emergency lights on a single platform. This leads to greater confidence that fire equipment is operational ready in times of emergency.

Active Fault and Failure Detection

The platform provides timely alerts to the Facility Manager when faults and failures are detected.

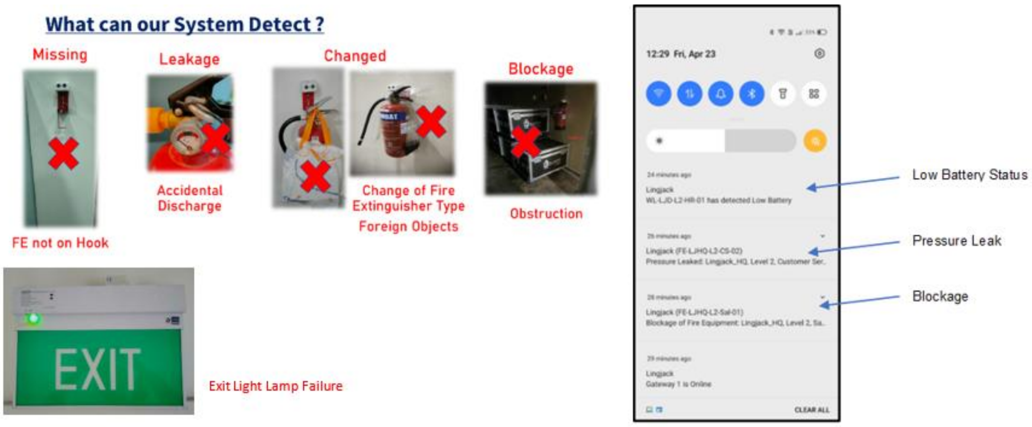


Figure 34. Faults and failures detectable by the platform

The FM team is informed of fault conditions through app alerts so they can be addressed promptly. The service incidents are captured through the platform, and this ensures that all incidents are promptly logged, tracked, and closed.

Reduced manpower for regulatory monthly inspections

The maintenance team can fulfil regulatory requirements for monthly inspections, records maintenance, incident records, corrective actions etc with reduced manpower, time, and effort. The team can spend more time on other value-added or critical tasks.

Step 3: Implementation/Deployment Model

The platform adopts Model B: Single Smart FM Solution and will include open APIs to integrate or exchange information with other FM platforms.

Step 4: Review Procurement Contract

The procurement was based on an initial capital investment with subscription model. A platform-as-a-service model could be explored as an alternative to lower initial capital investment.

Step 5: Track outcomes and review for continuous improvement

The performance was continuously monitored for improvements and the following outcomes were reviewed for continuous improvement:

a. The platform could replace the conventional practise of manual inspection and recording for fire extinguishers which results in manpower savings. This centralised archive allows for easy retrieval and maintenance tracking during audits.
b. The emergency lights and exit lights could be tested remotely on a scheduled basis, this reduces the manpower required for manual testing.
c. The monitoring feature provided timely alerts for fire extinguishers approaching service expiry which enabled timely servicing and replacement. A feature to automatically trigger service actions to external service vendors could be explored in the future.
d. The fault detection system was effective as it provided reliable and consistent feedback. The 24/7 monitoring enhanced the building's fire safety.

Carrying out monthly physical inspection of 200 fire extinguishers and exit lights will require about 4 to 5 days. More time will be required for larger developments. With electronic monitoring, the FM staff could focus on higher value activities.

Key lessons learnt

The following will be considered to enhance the system:

<u>Site survey to improve the wireless mesh connectivity</u>

The wireless mesh network is self-healing with redundancy features. Site survey is essential to identify potential disruptions due to site interference and to provide for alternate communication paths.

<u>Future expansion of the Smart Fire Safety and Emergency Platform</u>

In the April 2022 amendment of SS 578, electronic monitoring of fire extinguishers was included as an acceptable means to fulfil the regulatory monthly inspections. This would likely be extended to other fire safety systems, and these could be added to the Smart Fire Safety and Emergency Platform in future.

Interoperability between Smart Fire Safety and Emergency Platform and BMS Systems.

Although not identified as a requirement, it will be beneficial from the information captured to be integrated into the BMS or CMMS system. A bridging device that supports open standards eg. Modbus or an API could be developed for future integration.

C.3 Schindler Ahead

Towards end-2020, Schindler Ahead was installed in a prominent >500k sq. ft. business park in Singapore. The aim was to get better visibility and monitoring of the elevators in the building because it was a high-traffic area. The original maintenance contract for the building included maintenance, callbacks, and full repair coverage.

5-Step SMART Process

Step 1: Set Business Objectives and Outcomes

Identify Business Objectives

The building owner and FM manager have several objectives with regards to facilities management (FM). These include:

(1) Ensuring that facilities are working as expected and maintained adequately

(2) Ensuring that building tenants and building users are satisfied with the facilities

(3) Enhancing the building assets through maintenance and upgrading.

Set FM Outcomes

The following outcomes are desired by the building owner and FM manager:

(1) Reduce downtime/unavailability of facilities

(2) Increase building tenant and user satisfaction with facilities

(3) Improve building assets through maintenance and upgrading

Prioritise FM services

Elevators and escalators (E&E) are used hundreds of times daily by the building tenants and users. Smooth functioning of the elevators and escalators is essential for tenants and users to have a good experience in the property.

Step 2: Map Out Smart FM Solutions as Enablers

Schindler offers a remote monitoring solution called "Schindler Ahead", which includes the following capabilities:

(1) Remote monitoring: elevators are connected to Schindler's cloud and monitored 24/7 for any abnormalities or problems, allowing for prompt responses or pro-active interventions

(2) ActionBoard: ActionBoard is an online dashboard that allows customers to view the real-time status of elevators and check the history of actions performed on each elevator.

<table>
<tr><td rowspan="2">Type/Scope</td><td rowspan="2">Description</td><td>Building Level FM Services</td><td rowspan="5">Aggregating across Types 1 to 3</td><td rowspan="5">Demand side aggregation: Install Schindler Ahead across multiple buildings

Supply side aggregation: Installing Schindler Ahead will allow Schindler to collect and analyse more data from buildings</td></tr>
<tr><td>M&E Functions</td></tr>
<tr><td>Type 1: Digitalised Workflow Automation</td><td>When triggered by an incident, automatically initiates a process that tracks, logs, and closes the incident</td><td>- Elevator remote monitoring
- Automatic breakdown detection and technician dispatch</td></tr>
<tr><td>Type 2: Optimisation within systems</td><td>Use data analytics to:
- Optimize systems
- Quantify FM efficiency
- Perform preventive/predictive maintenance</td><td>- Perform proactive interventions to prevent more serious issues in the future
- Gather data from multiple connected units to improve diagnostic capability</td></tr>
<tr><td>Type 3: Integration across systems</td><td>Optimise resource deployment and utilisation across many systems</td><td>- Integration of Schindler API with building management system</td></tr>
</table>

Table 9. Schindler Ahead's capabilities differentiated into three types of "smartness"

Schindler Ahead includes all three types of "smartness".

Type 1: Digitalised Workflow Automation

Schindler connected a communications device called a Cube to each elevator controller. The Cube collects raw data from the elevator controller and sends it to the Schindler cloud for analysis. If any problems are found, they are sent to Schindler's technicians via an app on their company mobile phones. Technicians will then intervene as appropriate to either fix the problem or prevent a serious problem from occurring. Job details, actions to be taken, start time, end time and technician's comments are precisely logged in the mobile phone app. Schindler also has a Technical Operations Centre (TOC) in Singapore staffed by technical experts to provide additional guidance to the technicians where necessary

Type 2: Optimisation within systems

Data from connected equipment is routed to Schindler's cloud where it is analysed to produce "Symptoms", which either indicate a serious problem or a warning sign of a problem about to happen in the future. Schindler has a global team of technical experts in Switzerland and Germany who are constantly looking to improve Schindler's data analytics technology. On the ground, technicians provide feedback on the Symptoms through their company mobile phone, which also helps Schindler to improve the capabilities of its data analytics. Schindler has created an iterative feedback loop to collective harvest data from more connected units, leading to better performance of its analytics engine.

Type 3: Integration across systems

Schindler is currently developing a building integration toolbox and API platform that will allow the remote monitoring system to be easily integrated into building management systems.

Aggregation

For Schindler Ahead, aggregation occurs at both the demand side (customer side) and supply side (Schindler).

For demand side aggregation, the building owner has installed Schindler Ahead across multiple buildings in their portfolio. This has given them a bird's-eye view and better management of all the connected units.

For supply side aggregation, installing Schindler Ahead for many elevators in one building has allowed Schindler to closely monitor overall trends in problems, and fix them before more serious ones arise.

Step 3: Adopt Suitable Implementation Model

Current: Model B (Single Smart FM Solution)

The current model adopted by the customer is Model B, where the building owner has procured the Schindler Ahead service specifically and manages it through an online dashboard provided by Schindler. There is currently no integration between Schindler Ahead and any other Smart FM systems that the customer is using.

Long-term goal: Model A (Integrated Smart FM Solution)

Schindler is currently developing an open, secure, and modular building integration toolbox that allows customers to seamlessly integrate Schindler’s digital services into their overall building management and user experience by offering an Application Programming Interfaces (APIs) and other integration tools. Schindler aims to implement this new concept with its customers in the future.

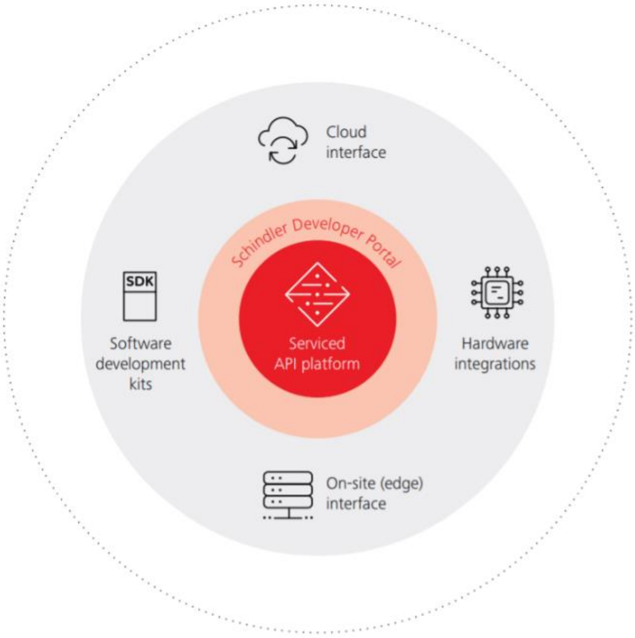


Figure 35. Schindler's Developer Portal

Step 4: Review Procurement Contract

The standard contract terms for Schindler ahead are as follows: an upfront installation fee for each Cube and a small monthly subscription fee per connected unit. Schindler recommends a contract duration of 3 years to gather adequate data about the performance of the connected units, which will help to improve the performance of the system. Schindler technicians will also be more experienced with the specifics of connected units if they service them over longer time periods.

Meetings are held between Schindler and operational stakeholders on the customer's side to track the progress of the remote monitoring system in improving maintenance outcomes.

Step 5: Track Outcomes and Review for Continuous Improvement

Schindler suggested that the following metrics be tracked to monitor the performance of remote monitoring:

(1) Equipment availability (uptime): to determine if the remote monitoring is helping to maximise the uptime of connected equipment

(2) Technical faults per equipment rate: to determine if the remote monitoring system is helping to reduce the number of technical faults per equipment

(3) Diagnostic accuracy: to determine how accurate Schindler's system is in determining the root cause of problems

Challenges

FM staff on the customer's side took some time to fully understand all the features of the Schindler remote monitoring system and the ActionBoard, and how to integrate these into their daily workflow effectively. Schindler staff were available to aid and answer questions where needed, and also to provide suggestions on how to best utilize the system.

Schindler also conducted internal training for its technicians before it was rolled out in the field.

Improvements/Benefits

Total number of technical callbacks per month decreased by 43% after installation of the cubes in the elevators.

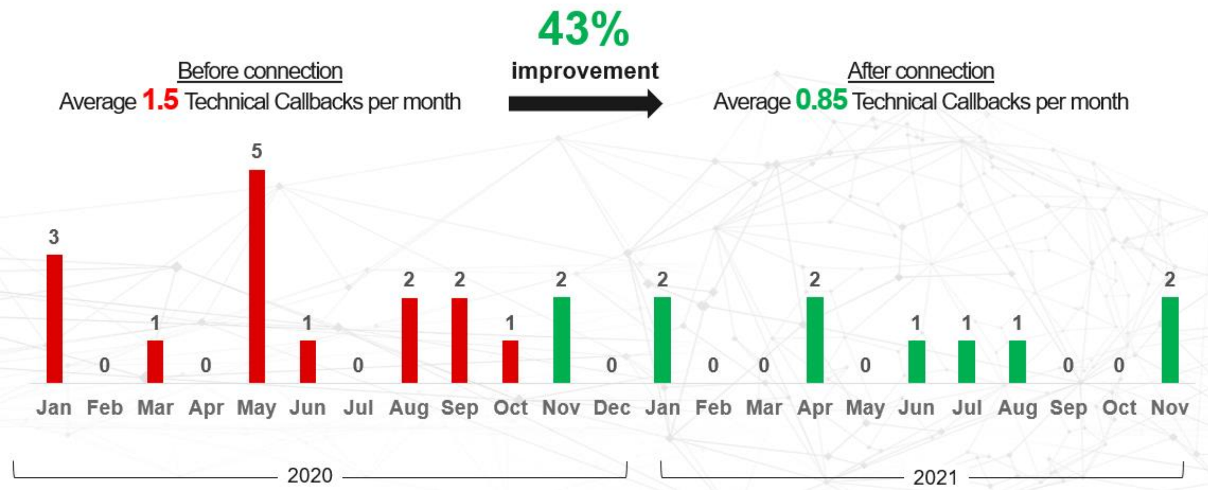


Figure 36. Reduction in technical callbacks after installation of the cubes in elevators

Total downtime per month decreased by 94% after installation of the cube - the remote monitoring diagnostics helped Schindler to solve a few big problems with the elevators.

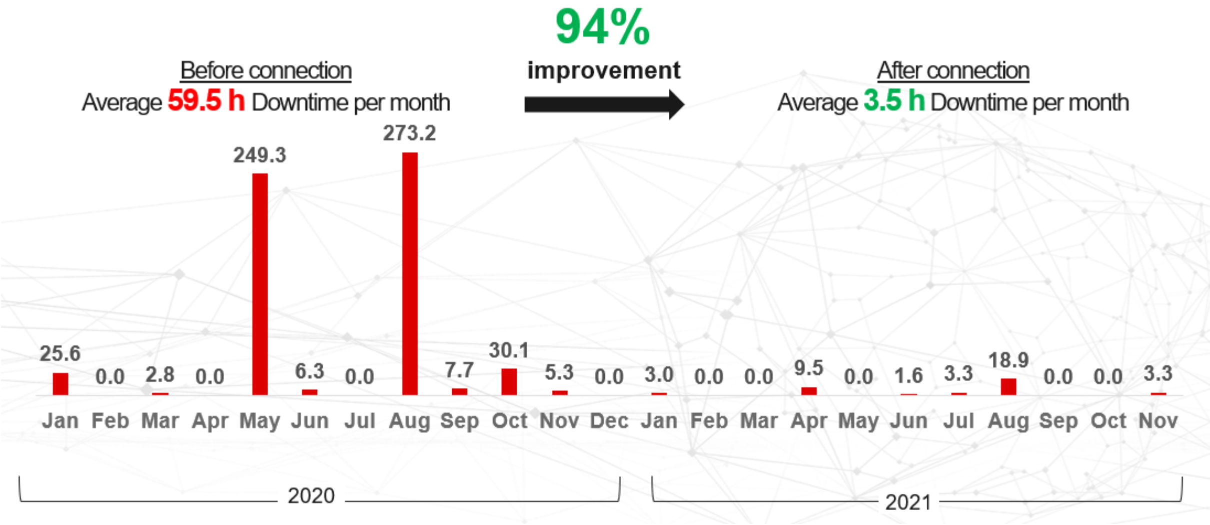


Figure 37. Reduction in downtime after installation of the cubes in elevators

Key Lessons Learnt

Schindler's technology is highly effective in monitoring elevators 24/7. However, efforts are also needed on the human side, both by the customer in monitoring the equipment, as well as on Schindler's side to perform proactive interventions before more serious problems arise.

In the near future, Schindler intends to go one step further, by rolling out its API platform to integrate each customer's Building Management System with Schindler Ahead monitoring. This will allow for comprehensive monitoring, better visibility, and enhanced outcomes of all the facilities in a building.

C.4 J-Ops Command Centre, JTC Corporation (JTC)

Overview

JTC is the lead agency to spearhead the planning and development of industrial infrastructure in Singapore. Over the years, JTC has developed over 7,000 hectares of industrial and 4 million m^2 of ready-built facilities. With a growing portfolio of properties, JTC embarked on developing the J-Ops Command Centre to address changes in the FM landscape and to seek sustainable and effective solutions for better manpower and resource deployment.

JTC's J-Ops Command Centre is one of the first integrated building and estate operations command centres in Singapore. It houses multiple Smart FM systems with functions such as workflow automation (Type 1), building optimisation (Type 2) and estate monitoring (Type 2). These systems allow JTC to remotely monitor and manage FM operations for most of its developments and estates across the island.

With the J-Ops Command Centre, FM Managers from JTC are able to pull data from more than 115,000 data-points connected to 23 of its buildings, to analyse and achieve improvements in tenant comfort, reduction in energy leakages, and efficiencies in resource deployment.

JTC's FM transformation journey is summarised below based on the 5-step SMART process:

Step 1: Set Business Objectives and Outcomes

The management of JTC's growing portfolio of facilities at such an extensive scale has given JTC the oversight to identify and pinpoint the following key challenges that needs to be addressed at the higher level:

i. Growing and ageing pool of buildings and infrastructure
ii. Rising operating and energy costs
iii. Manpower constraints

iv. Laborious vendor management across large number of contracts and services

v. Increasing customer expectations on level of service delivery

vi. Need for better access to data and communication between different building management systems (BMS)

To address these challenges, JTC identified and set the following business objectives, FM outcomes and high-priority FM services to focus on:

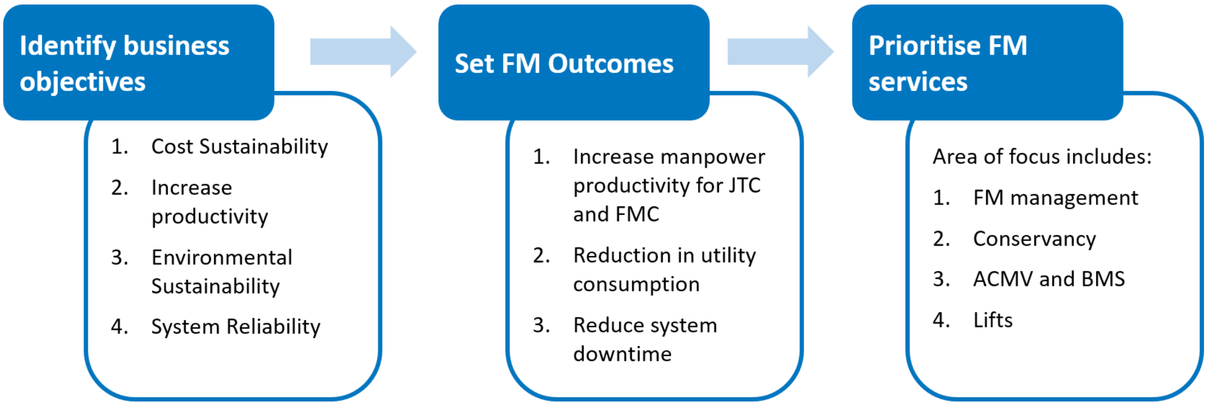


Figure 38. JTC's Step 1 SMART Process

Step 2: Map Out Smart FM Solutions as Enablers

The J-Ops Command Centre was conceptualised with these challenges and business objectives in mind. Further to selecting the high-priority FM services, JTC proceeded to identify smart solutions for each FM services that can meet the business objectives and desired FM outcomes.

Table 8 below maps out the smart solutions identified by JTC under the Smart FM Framework. These smart solutions were subsequently implemented under the J-Ops Command Centre.

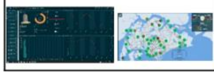
	Scope	FM Services			
		FM Management	Conservancy	ACMV & BMS	Lifts
Type 1	Digitalise asset	FEMS: Floor plans; O&M manuals; Maintenance regime; M&E equipment; Maintenance team; Tenant information			
	Workflow automation	• Estate monitoring system • Report-a-Fault-App	• Smart Bins • Integrated Toilet Management Solution	• Temperature control at finger tip	• Lift Monitoring System
Type 2	Optimisation within systems (data analytics)			Building Optimisation System 	Smart Lift Performance Management System 

Table 10. JTC's Smart FM Framework

Facilities & Estate Management System (FEMS) (Type 1)

JTC adopted the FEMS, an automated workflow system, that digitised all FM-related work orders. This helped the FM Managers automate their existing work processes and enhance the efficiency of their service delivery.

Feedback provided by customers and tenants on facility faults and issues are first documented and tracked in the system, before being routed to the respective FM Managers and/or technicians to resolve.

Estate Monitoring System (Type 1)

The J-Ops Command Centre houses an Integrated Estate Monitoring System that pulls video feeds from closed circuit televisions (CCTVs) deployed at more than half of JTC's estates and developments.

The system has integrated customised video analytics to bring potential security occurrences to the attention of the Security Team. Required response and checks on the ground can then be activated quickly.

Lift Monitoring System (Type 1)

The J-Ops Command Centre includes a Lift Monitoring System that uses non-intrusive sensors on existing lifts to monitor real-time and historical utilisation data as well as abnormal behaviors, and track maintenance activities.

Smart Bins (Type 1)

JTC also deployed over 40 Smart Bins across its estates and developments. These smart bins are solar-powered, cloud-connected and self-compacting to eliminate bin overflows.

The system dashboard can be accessed from the J-Ops Command Centre to understand waste patterns, optimise collection routines and improve manpower productivity and deployment.

Building Optimisation System (Type 2)

Last but not least, the Building Optimisation System (BOS) is a cloud-based system that allows JTC to centrally and remotely monitor, analyse and optimise the performance of their portfolio of buildings.

The BOS collects real-time operating data, across 39 JTC buildings, from different equipment within building sub-systems such as Air Conditioning and Mechanical Ventilation, Electrical, Fire Protection, Lifts and Pumps systems. The system has analytical and diagnostic capabilities to help JTC's FM Managers detect and rectify inefficiencies.

Figure 39. J-Ops Command Centre's Building Optimisation System

Step 3: Adopt Suitable Implementation Model

After identifying the smart solutions, JTC moved on to select a suitable implementation model for each solution (see *Figure 37*). Based on JTC's experience, some useful pointers to note when doing so include:

i. For solutions with larger scale and scope, implementation model A may be considered. Considerations between solutions that are to be acquired and operated by building owner vs solution as a service would need to be assessed based on market maturity of the solution, ease of implementation as well as economies of scale. It is notable that implementation model A is not recommended in a managing agent model given the implementation may be hindered with too many parties involved.

ii. For ad-hoc services, as well as services and solutions that are proprietary in nature, implementation model B may be considered. It is notable that solutions that achieve market maturity and are to be scaled would then move to be implemented using model A.

It is important to reiterate that none of the implementation models are superior to another. The type of implementation model to adopt depends on the individual organisation or building's mode of operation.

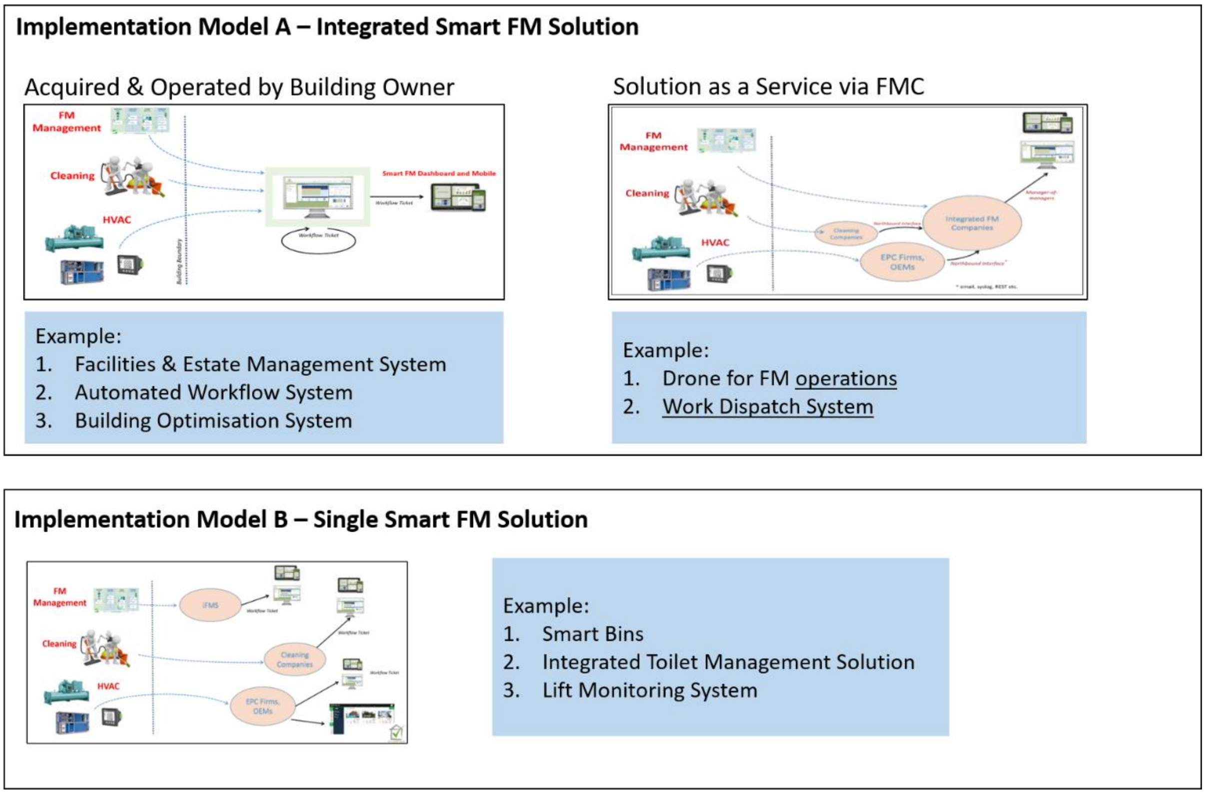


Figure 40. Implementation models adopted by JTC for various Smart FM solutions

Step 4: Review Procurement Contract

Almost all of JTC's properties undertake the integrated FM contracting. Through the amalgamation of FM contracts, JTC reduced the number of service contracts by 42%. The increase in scale and value of the contract, as well as longer contract period, also made economic sense for JTC's service partners to invest in manpower development and adopt suitable building technologies.

Figure 38 below summaries the considerations JTC had when reviewing their procurement contracts.

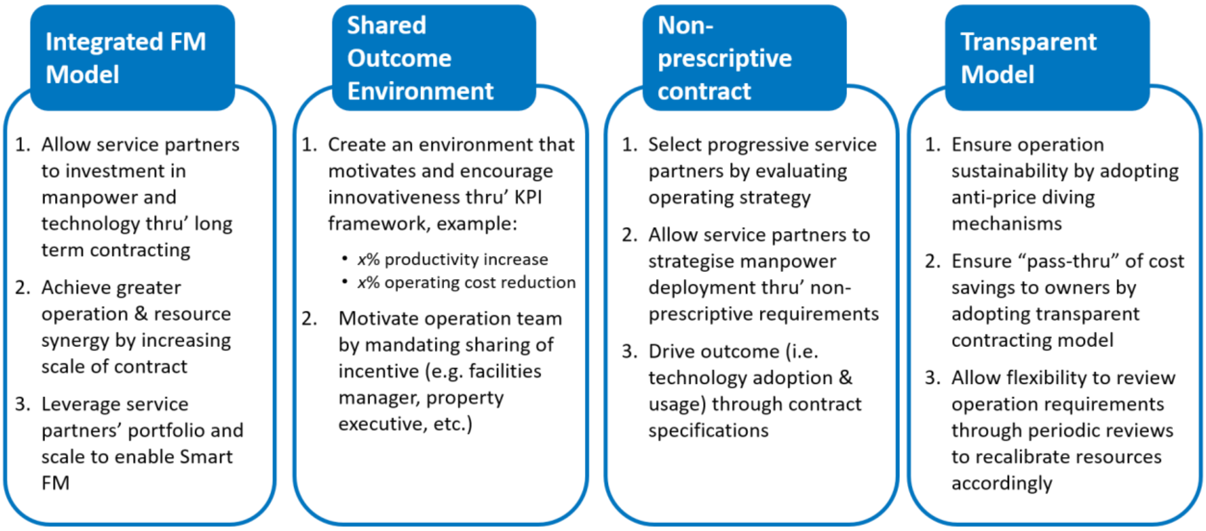


Figure 41. JTC's Considerations for Procurement Contracts

Step 5: Track Outcomes and Review for Continuous Improvement

For continuous improvement, JTC tracked and reviewed each of the Smart FM solutions implemented. The benefits of undergoing the FM transformation change in their operations include:

Improved Effectiveness of FM Services with Centralised Monitoring and Management

By consolidating the monitoring and management of their multiple FM operations, estates and developments at the J-Ops Command Centre, JTC is able to optimise their resources, improve their FM Team's knowledge base and streamline various coordination and organisation processes, increasing productivity.

The integration of multiple brands of BMS into an open and organised communication protocol, and with standardised naming conventions for the BMS data points, has also reduced confusion and eased the overall monitoring of building performance across JTC's portfolio of buildings.

Ease of Access to Comprehensive Database to Carry Out Data Analytics

Data from connected buildings across the island are stored and organised in a cloud storage. With a comprehensive database that is easily accessible, JTC can carry out data analysis on different areas to provide better insights for improvements in current FM operations and the design of future buildings.

Enhanced Service Delivery with Pre-emptive Maintenance and Improved Response Time

The intelligent fault detection systems ensure problems are detected before they escalate, resulting in fewer equipment breakdowns. The Automated Workflow System has also improved process efficiency and shortened response and rectification time. This not only enhanced user experience and reduced feedback from them, it also allowed JTC to avoid unnecessary costs with the buildings constantly performing at an optimal state.

Key Lessons Learnt

The following design specifications should be considered for future projects to facilitate the adoption of Smart FM:

Standardised Naming Convention to Enable Monitoring and Management Across Portfolio of Buildings

With many of their BMS using different naming conventions and some with closed communication protocols, JTC had to spend additional time and effort to standardise the naming convention and clean up the data points across all the buildings managed by the J-Ops Command Centre. Only then can these buildings be effectively linked back to the Building Optimisation System. A standardised naming convention will allow the FM Managers to better troubleshoot issues and increase productivity.

Interoperability Between Systems to Facilitate Data Transfer and Systems Integration

With multiple systems housed under the J-Ops Command Centre, JTC had to ensure that all the systems are designed with an open communication protocol and the data can be pushed and aggregated in a cloud storage. The systems should also allow for 3rd Party Application Programming Interface (API) connections. By doing so, data transfer between systems can be made possible and facilitate the future integration of different systems if there are synergistic gains.

C.5 Yale-NUS College: Aggregated Infrastructure Health and Integrated Performance Dashboard

Overview

Constructed in 2015, Yale-NUS College is a 63,000 m^2 campus comprising three residential colleges where students live in, and become active members of, during their four years of study. The campus facilities are managed by a 14-man Infrastructure, Safety & Security Office who oversees more than 30 term FM service contractors.

In 2019, the Office developed and deployed MyInfra app, a Type 1 Smart FM workflow automation mobile application, to streamline and optimise the incident reporting and closure process. Since then, the Office has been collecting the data and developed a Smart FM platform/dashboard that process the data into insights. As the platform/dashboard is developed in-house, no outsourcing and variation cost are needed. Today, the FM team is using the platform/dashboard to self-assess and deal with the areas of concern directly which has reduced daily operational meetings with the overall savings of about 4,384 man-hours in a year.

Smart FM Programme

The Yale-NUS community used various communication channels, such as emails, MyInfra app, and phone calls, to contact the Officers-In-Charge (OICs) to request for assistance and/or report issues. On average, the Office receives 6,000 feedbacks a year ranges from service requests to defect reports from the students, faculty, and staff. To gain insights from all the feedbacks, a Smart FM programme was initiated based on the **People, Process, and Technology** framework:

1. ***People**: Building Digital Skills of FM team*

Four out of 14 staff (including the head of department) attended company-sponsored training in data analytics and software-related courses. The staff would then develop an in-house FM platform/dashboard that embed real-time data and present prevailing performance levels of operations and maintenance. Since the platform was developed in-house, the staff can make quick system variations to the platform themselves without the delays often associated with the external intervention.

All staff from various trades regardless of their designations are also empowered to adopt available technology/tools such as "myInfra" app to report defects, QR code, and GPS system to communicate more effectively and improve operational response in the event of emergencies.

2. ***Process**: Streamlining FM Workflow*

The FM workflows were then assessed and streamlined by leveraging on multi-functional roles:

- Security and janitorial staff - security officers on patrol and janitors on duty to look out not only for security breaches but also infrastructure defects to be raised and rectified before the users see and report them the next day. A flexible incentive and recognition scheme was put in place to attract participation.
- Maintenance staff - the maintenance officers to complete certified licensing courses on security-related duties such as the operations of the Fire Control Centre and guard duties. They also become a contingent resource for college events or covering officers in the event of absenteeism. This proved particularly useful during the COVID-19 pandemic.

Staff of vendors at the executive levels are invited to attend regular operational meetings where the progress of every outstanding case is deliberated and updated. In such meetings, managers and other team members openly contribute suggestions to address the feedbacks, be it service requests or defect reports.

3. ***Technology**: Developing In-house FM Platform/Dashboard*

The Infrastructure, Safety and Security Office self-initiated and developed an in-house FM platform that has multiple dashboards to display at least 42 Key Performance Indicators (KPIs). At the heart of the dashboard is a real-time Campus Health Index which is a composite index that reflects the current state of its ease of maintenance, impact on customer service, staff performance, safety, and sustainability.

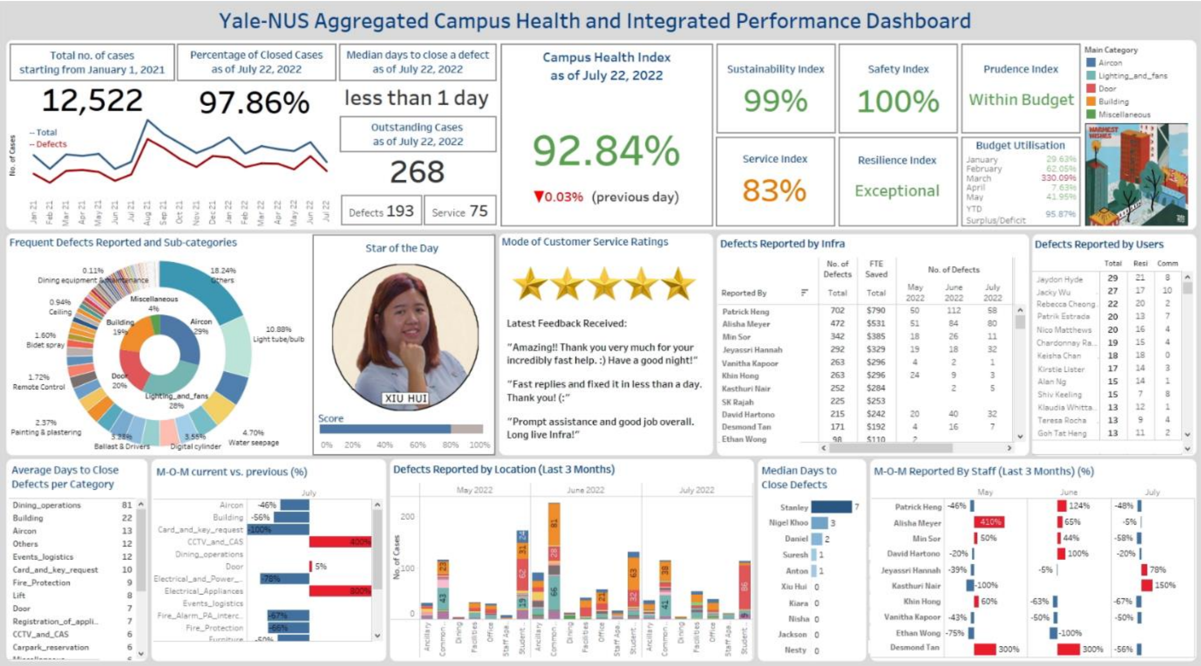


Figure 42. The real-time visualisation dashboard is developed by the FM team at less than $10,000 with 2 months of implementation timeline[13]

At the backend, the campus health index is developed and tested by applying multi-linear regression analysis to establish a relationship between one or more independent variables such as the Safety Index, Sustainability Index and Customer Service Index. This process is iterative and periodically reviewed until the Campus Health Index is a refined health indicator of the Office's "central nervous system".

The implementation runway of the dashboard was less than two months. During this time, the campus health and performance index was kept above 90 per cent and there was no considerable need to incur additional financial and manpower resources.

Impact of the Smart FM programme

In addition to the financial and productivity savings achieved, the Smart FM programme also benefited Yale-NUS in terms of:

[13] Images shown are for illustration purposes only and may not be an exact representation of the dashboard. Credit: Yale-NUS College

1. <u>*Improvement in Customer Service through Proactive Maintenance*</u>

After implementation, Infra Team's turnaround (median days to close defects) improved by 25 per cent within four weeks due to the dashboard's ability to immediately recognise and flag contributions from the staff.

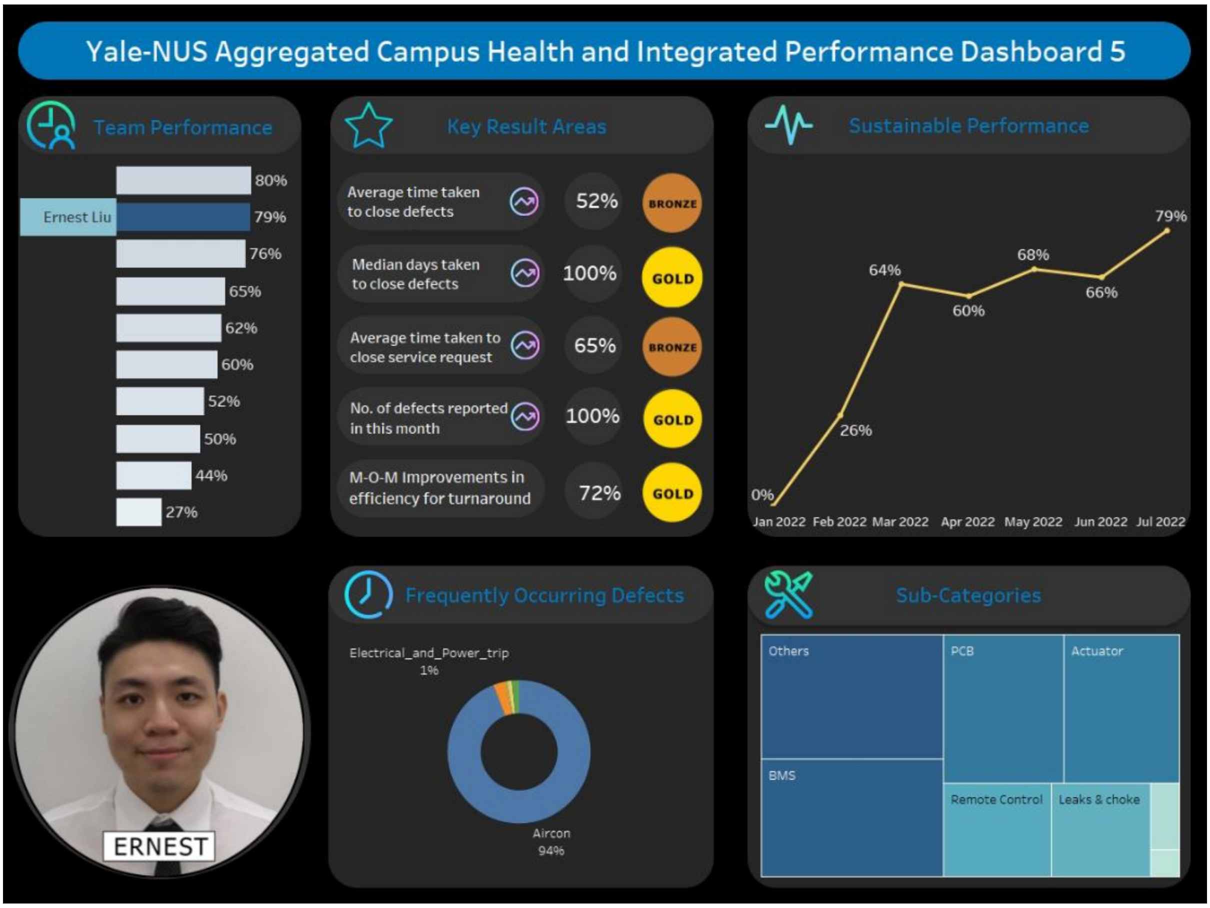


Figure 43. The real-time visualisation dashboard is able to reflect the team's performance, time taken to close defects and the frequently occurred defects[14]

The amount of feedback on defects from the internal end-users (est. 1,000 students + 223 staff/faculty) also dropped by 22 per cent, corresponding to a 128 per cent increase in feedback on defects reported by the in-house and outsourced staff from the Office ("Infra Team"). This is indicative that the end-users are reporting lesser defects in the common area as the FM teams are picking them up and remediating them before end-users even see or experience them.

[14] Images shown are for illustration purposes only and may not be an exact representation of the dashboard. Credit: Yale-NUS College

2. *Contributions to Safety, Financial, and Environmental Sustainability*

As defects are now proactively reported by the Infra Team, an early intervention and remedy will mitigate wastage in utilities and improve safety and economic lifespan of the property asset. For example, a water stain mark in the ceiling at a common area was reported even though it did not appear to be a serious matter. It was then discovered that the water mark came from a pin hole leak in a high-pressure water pipe that if left unattended it might burst and incur much higher cost for damage control, downtime and reinstatement. In another example, pools of water sometimes did not subside after a heavy rain which may be easily dismissed as a post-storm effect. A staff assessed and reported that one of the spots was not draining efficiently and the team then discovered there were debris that choked the gutter and cleared it before mosquitoes can breed.

3. *A More Inspired and Motivated Team*

The FM dashboard tracks “live” cases that are outstanding and the time taken to close the incidents and filters most frequently occurring problems for analysis. It also gives real-time appraisal on staff performance that is transparent to all which has motivated the staff to work harder to close the case and inspired them to be at the top of the chart. This approach creates a culture of self-awareness and self-appraisal.

The multi-functional integration and dashboard implementation have also reduced staff workload and gave them easier and faster access to information to analyse what and when things go wrong.

As the management has 24x7 access to the dashboard through desktop or mobile application, they can now check the health and performance of the campus' building services and operations at their convenience and use the data to help them in decision making process.

Assuring Continued Excellence

Moving forward, the dashboard will be enhanced to display 150 universal KPIs up from the current 42. A Virtual Manager (VM) will be introduced to supervise the works that would be carried out for most of the cases that can be closed within one day. A challenge given to the VM is to reduce the probability of the same problem recurring within a short span of time.

The success of this Smart FM programme is due to the team's continuous strive for operational excellence and taking the ownership of the data to construct a comprehensive management system that foster trust and confidence among staff and contractors. The integrity of the data is paramount in ensuring that the visualisation is accurate so that the relevant analytics can be performed at the earliest opportunity. Hence, the Office undergoes ISO 41001:2018 Facilities Management external audit every year to ensure there is a process of validation and continual improvement.

C.6 Smart Energy Management for ACMV Systems

Smart Energy Management refers to the use of advanced technologies and data-driven solutions to monitor, control, and optimise the generation, distribution, and consumption of energy. This approach aims to improve energy efficiency, reduce costs, and minimise environmental impact.

Smart Energy Management (SEM), particularly in the context of ACMV (Air Conditioning and Mechanical Ventilation) systems, is an emerging solution that has evolved as a response to the growing demand for energy efficiency and environmental sustainability. Traditionally, ACMV systems operated on set schedules or fixed set of control set points, often leading to energy wastage or missed opportunity for saving energy. However, advancements in technology have led to the integration of sensors, automation, and data analytics into ACMV systems, enabling real-time monitoring and adaptive control. This allows for more dynamic control adjustments to respond to a wider set of changing parameters such as occupancy density, human traffic flow and weather conditions.

This guide highlights a case study on SEM for ACMV systems by Azendian, but there are several other similar market solutions that building owners and FM companies can explore and pilot. It is also important to note that for such data-driven solutions to be effective, it has to be applied with a sound understanding of the domain knowledge of ACMV systems, and complemented by a robust maintenance regime. Otherwise, the potential savings may not be achieved.

Building owners should also consider the various implementation and business models. Some incorporate these solutions into the ACMV maintenance service contracts, while others adopt a performance-based model, sharing the savings realised from implementing the solution. Alternatively, building owners may acquire the solution as Software-as-a-Service (SaaS) or require their Facility Management Companies (FMCs) to implement it in partnership with the SEM providers.

Begin your Smart Energy Management journey today to achieve substantial energy savings and enhance the sustainability of your building operations.

Azendian Estate HVAC Energy Optimisation Solution

Products and solutions in the market, such as variable speed drives and building automation systems, are often limited in their ability to optimise energy usage in real-time, relying on manual readjustments of equipment settings. In contrast, the Azendian Estate solution offers real-time monitoring and adaptive control for chiller plants and AHUs. By applying AI and ML, it automatically adjusts setpoints in real-time, ensuring optimal HVAC performance under all conditions.

The solution analyses data from various sources, including weather forecasts, building usage patterns, and chiller plant performance, to optimise energy usage. Based on changes in building usage and weather conditions, the solution writes back operating parameters in real-time to the models and adjusts the setpoints according to the model's outcomes.

The Azendian Estate HVAC Energy Optimisation Solution offers several key benefits for buildings and organisations:

1. **Brand-Agnostic and Non-Intrusive Integration**: The solution seamlessly integrates with any ACMV system without requiring major modifications or replacements.
2. **Minimal Upfront Investment**: With little to no initial costs, organisations can quickly realise benefits and achieve a shorter Return on Investment (ROI) period.
3. **Unified Control Platform**: It digitises multiple assets, consolidating them under a single control platform for simplified ACMV management.
4. **Cloud-Based Access**: The cloud-based system allows for remote access anytime, anywhere, providing flexibility for building managers and operators.
5. **Real-Time Write-Back Capability**: Changes made to the system are reflected immediately, enabling instant feedback and faster decision-making.
6. **Energy Savings**: The solution optimises ACMV performance, reducing energy costs and CO_2 emissions.

Case Study for Chiller Plant Optimisation

Background

Building General Info	:	19 storeys grade A office building (GM platinum) at CBD (Singapore)
Estimated Area Served	:	+/- 35,000 sqm
Year Built	:	2009
Cooling Load Profile	:	Office hour: 500 – 650RT After Office hour: 50 – 150RT
Operating Hour	:	

Time	**1 Chiller in Operation**	**2 Chiller in Operation**
Monday to Friday	6pm – 7am the following day	7am – 6pm
Saturday	1pm – 7am the following day	7am – 1pm
Sunday/Public Holiday	24 hours	-

Chiller Plant Components	:	4 Chillers 4 Chilled Water Pumps 4 Condenser Water Pumps 2 Cooling Towers

Chiller Plant Performance	
Annual Cooling Demand (RTh/year)	2,555,333
Annual Chiller Plant Energy Consumption (kWh/year)	1,806,729
Annual Chiller Plant Utility Cost (SGD) *(Assume Elec Tariff @ SGD 0.34/kWh)*	~ 610,000

Project Details

1. Initial site assessment and exploratory data assessment:
    a. Recommendations were provided to the client to rectify chiller plant operation issues.
    b. Faulty temperature sensor replacement.
    c. The existing chiller plant was found to operate at modulating speed with a Variable Speed Drive (VSD) but at fixed set points.

2. Baseline Methodology:
    a. A regression model is developed to calculate the chiller plant's baseline consumption, capturing various scenarios of power consumption under different weather conditions and cooling loads.
    b. A polynomial equation is then generated to calculate the chiller plant's baseline power consumption (kW). This equation considers the cooling load (RT) and wet-bulb temperature (℃), which represent variables related to building occupancy and weather conditions.
    c. To further improve the accuracy of the baseline, multiple polynomial equations are generated for different cooling load distributions.

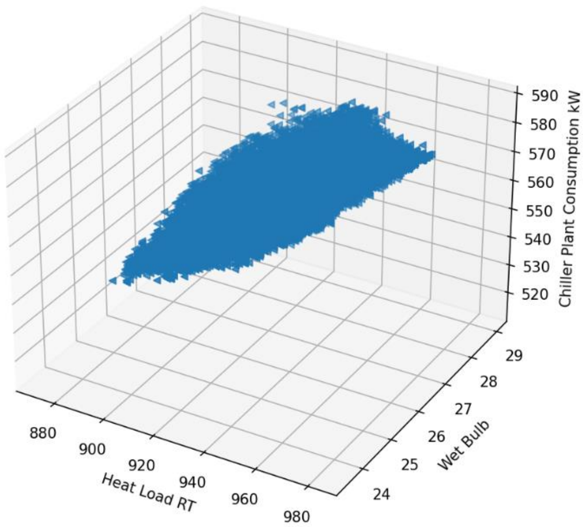


Figure 44. Example of baseline for a load range

3. Implementation: A centralised cloud solution was deployed with a dedicated connection to the existing BMS system, as illustrated in Figure 45 below. To comply with the building owner's IT policy, the gateway was configured within a DMZ, enabling interface with the existing BMS while routing through the firewall.

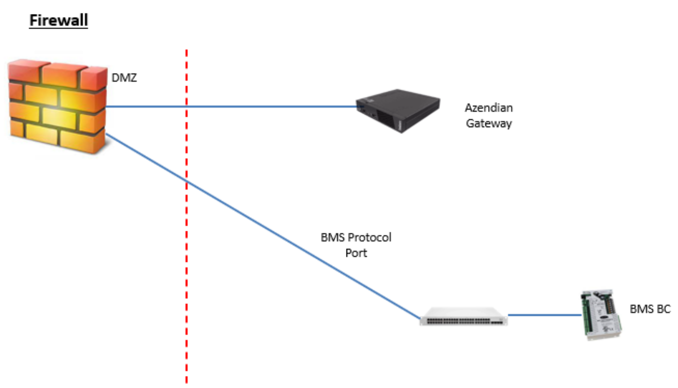


Figure 45. Centralised cloud solution deployed with a dedicated connection to the existing BMS system

Project Outcomes

Chiller Plant energy savings summary:

	A	B	C	C-B	(C-B)/C
Date	**Cooling Load (RTh)**	**Chiller Plant Energy Consumption (kWh)**	**Chiller Plant Baseline Energy Consumption (kWh)**	**Energy Savings (kWh)**	**Energy Savings (%)**
April	194,567	140,575	156,003	15,428	9.89%
May	198,430	145,418	158,978	13,561	8.53%
June	209,590	149,219	169,383	20,164	11.90%
July	197,587	139,278	157,714	18,436	11.69%
August	216,976	147,989	172,471	24,482	14.19%
Sep	194,805	135,120	159,069	23,949	15.06%

Table 11. Summary of Chiller Plant energy savings

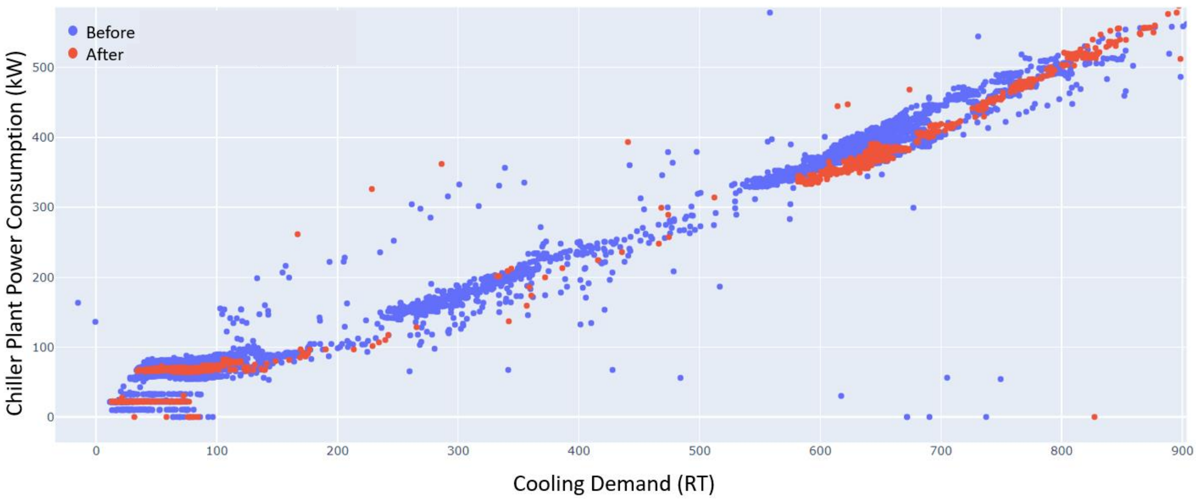


Figure 46. Chiller Plant Power consumption before and after implementation

Case Study for AHU Optimisation

Background

Building General Info	:	7-Storey of multi-purpose building comprises of offices, data centre, laboratory, F&B, and exhibition hall (Singapore)
Estimated Area Served	:	+/- 30,000 sqm
Year Built	:	2013
Overall Operating Cooling Demand	:	100 to 600 RT
AHU Quantity	:	20 nos
Operation Hours	:	24 hours operation

Project Details

1. Initial site assessment and exploratory data assessment.
2. Baseline Methodology: The baseline for AHU power consumption (kW) is established based on the historical power consumption profile over a specified period, using daily reference data. A sample of the AHU power consumption baseline (kW) is shown below.:

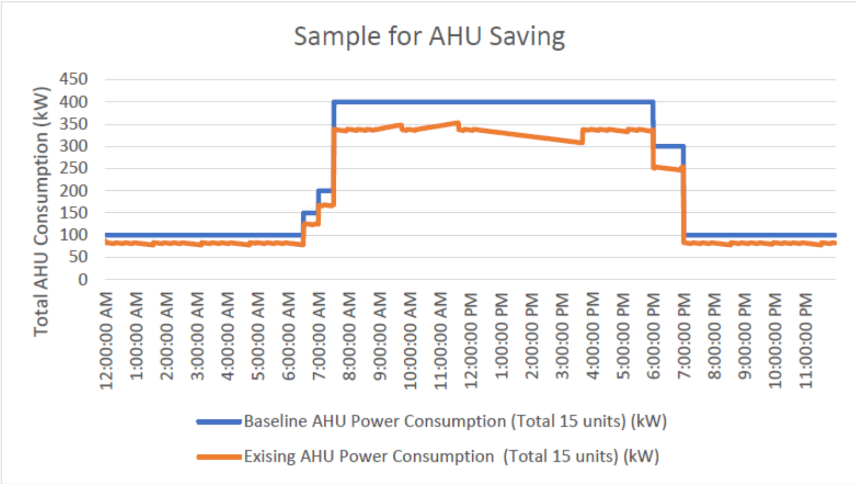


Figure 47. Sample for AHU Saving

3. Implementation: A centralised cloud solution with dedicated connection to the airside system, as shown in Figure 48.

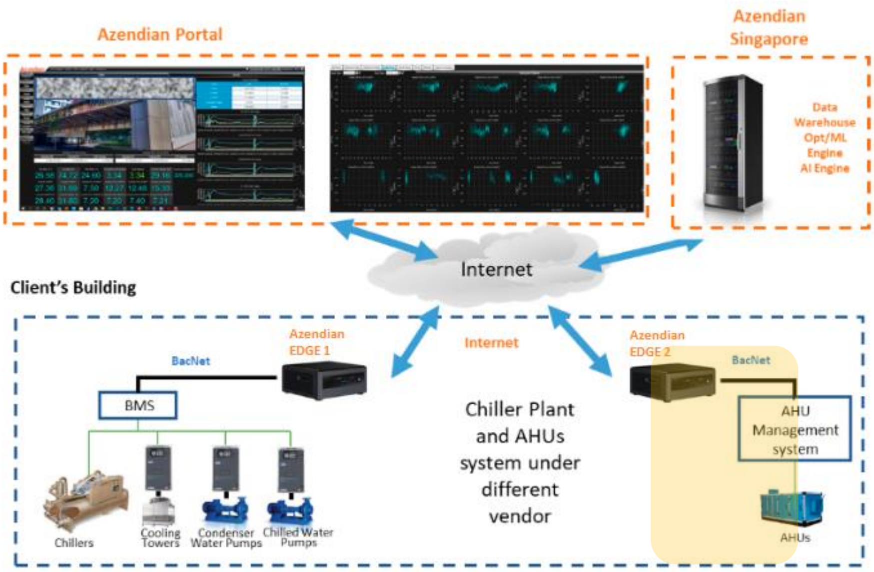


Figure 48. A centralised cloud solution connected to the airside system

Project Outcomes

AHU energy savings summary:

	A	B	B - A	(B-A) / A
Month	**Total Energy Consumption (kWh)**	**Total Baseline Consumption (kWh)**	**Total Energy Savings (kWh)**	**Total Energy Savings (%)**
Aug-22	22,814	40,695	17,881	43.94%
Sep-22	24,223	42,608	18,385	43.15%
Oct-22	27,621	48,917	21,296	43.54%
Nov-22	30,579	52,448	21,969	41.89%
Dec-22	23,758	46,205	22,448	48.58%
Jan-23	27,630	53,415	25,785	48.27%

Table 12. Summary of AHU energy savings

Conclusion

The deployment of the Azendian Optimization Solution in both case studies achieved significant energy savings, ranging from approximately 9% to 15% for the chiller plant and 42% to 49% for the AHU. The application of data science to ACMV optimisation has proven highly beneficial, particularly through a machine learning algorithm that continuously learns from changes in equipment behaviour and load profiles as new operational data is collected. Over time, the algorithm retrains itself to adapt and optimise the plant under varying conditions.

Appendix D: Fault Detection & Diagnostics

In general, the FDD sequence can be illustrated in the flow diagram below.

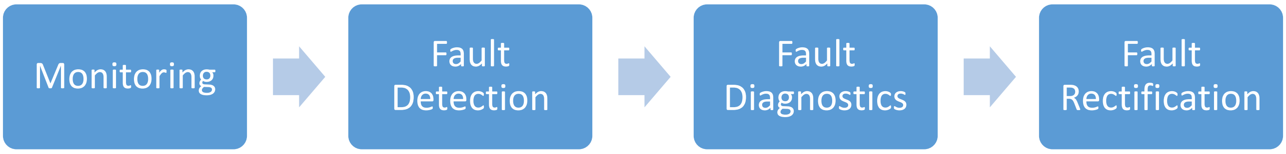


Figure 49. Fault Detection and Diagnostics flow diagram

Monitoring is a pre-requisite for FDD where it depends heavily on the input from the sensors where the type and quality of the monitored data is determined by the method used in identifying the faults.

Fault Detection is identifying that a problem has occurred, even if the root cause has yet to be identified. Fault may be detected from a single variable (e.g., alarm based on high, low, or deviation limits for a process variable) or multi variables. The fault detection method may adopt rule-based algorithm or more advanced techniques such as machine learning functions.

Fault Diagnostics is pinpointing one or more root causes of the problems where corrective action can be taken. A metadata model following an Open Metadata Schema can be developed to facilitate efficient and accurate analytics of the faults and reporting of the diagnostics.

Fault Rectification is usually a corrective action to prevent further recurrence of the failure, for example through reactive or preventive maintenance activities. It may include the use of a Computerized Maintenance Management System (CMMS) to track the status of the action either to inspect or fix the fault.

To get started on the journey to use FDD, building owners can make reference to the basic parameters that should be monitored for each system in this section.

1. Chiller plant

Main Equipment

BMS monitoring points	Individual Equipment Level			Plant Level
	Chillers	Chilled water and condenser water pumps	Cooling Towers	Chilled water and condenser water headers
Running status (on /off)	√	√	√	
Control valve (open / close)	√	√	√	
Bypass valve (open / close)				√
VSD		√	√	
Selector switch mode (auto / manual / off)	√	√	√	
Trip alarm	√	√	√	
Chilled water supply temperature	√			√
Chilled water return temperature	√			√
Condenser water supply temperature	√			√
Condenser water return temperature	√			√
Chilled water flowrate	√			√
Condenser water flowrate	√			√
Electrical current	√	√	√	
Electrical voltage	√	√	√	
Electrical consumption	√	√	√	
Electrical breaker status (on / off / trip)	√	√	√	
Differential pressure				√ chilled water header only[15]
Running time	√	√	√	
Individual chiller's internal operating parameters, e.g. running state, refrigerant pressure, saturated refrigerant temperature, discharge temperature, oil pressure and temperature[16]	√			

Table 13. Chiller plant – BMS monitoring points

[15] Differential pressure sensor is also required within chilled water system to regulate the pumps
[16] These are available via the BACnet or Modbus communication interface of a chiller

Electrical – Motor Control Centre (MCC) Panel

- Incoming supply breakers status (on / off / trip)
- Outgoing breakers status (on / off / trip)
- Bus coupler status (on / off / trip)

Others

- Refrigerant leak detector
- Condensate water quality
- Chemical treatment pump status (on / off) and trip alarm
- Make-up water tank level alarm (low / mid / high / emergency high / overflow)
- Make-up water pump status (on / off) and trip alarm
- Weather-station

2. Air Distribution System

Air Conditioning Equipment

BMS monitoring points	Fan coil unit	Pre-cooled air handling unit (PAHU)	Air handling unit (AHU)
Running status (on /off)	√	√	√
Control valve (open / close)	√	√	√
VSD		√	√
Selector switch mode (auto / manual / off)	√	√	√
Off coil temperature		√	√
Air damper position (open / close)		√	√
Trip alarm	√	√	√
Smoke detector alarm		√	√
Primary filter differential pressure		√	√
Secondary filter differential pressure		√	√
Chilled water supply temperature		√	√
Chilled water return temperature		√	√
Chilled water flowrate		√	√
Return air temperature	√		√

BMS monitoring points	Fan coil unit	Pre-cooled air handling unit (PAHU)	Air handling unit (AHU)
Duct pressure sensor		√	√ variable air volume only
Variable air volume (VAV) box			√ variable air volume only
Carbon dioxide sensor			√
Electrical consumption	√	√	√
Running time	√	√	√

Table 14. Air Conditioning Equipment – BMS monitoring points

Mechanical Ventilation Equipment

BMS monitoring points	Fresh air and exhaust fans	Carpark MV and jet fans
Running status (on /off)	√	√
VSD	√	√
Selector switch mode (auto / manual / off)	√	√
Trip alarm	√	√
Carbon monoxide sensor		√
Electrical consumption	√	√
Running time	√	√

Table 15. Mechanical Ventilation Equipment – BMS monitoring points

3. Electrical System

Transformer

- Temperature alarm
- Trip alarm

Low tension main switchboard

- Incoming supply breakers status (on / off / trip)
- Power consumption – incoming supply
- Outgoing breakers status (on / off / trip)
- Power consumption – outgoing supply
- Bus coupler status (on / off / trip)
- Automatic Transfer Switch

Standby generator

- Running status (on / off)
- Trip alarm
- Selector switch mode
- High temperature alarm
- Diesel day tank high level alarm
- Diesel day tank low level alarm
- Battery status
- Circuit breaker status (on / off / trip)

Sub – switchboard and distribution board

- Incoming supply breakers status (on / off / trip)
- Power consumption – incoming supply
- Lighting status (on / off)

4. Plumbing and Sanitary System

Plumbing – Domestic water system

- Transfer pump and booster pump running status (on / off)
- Transfer pump and booster pump trip alarm
- Transfer pump and booster pump power consumption
- Transfer pump and booster pump selector switch mode (auto / manual / off)
- Transfer tank and storage tank level alarm (low / mid / high / emergency high / overflow)

Sanitary – Ejector system

- Ejector and sump pump running status (on / off)
- Ejector and sump pump trip alarm
- Ejector and sump pump power consumption
- Ejector and sump pump selector switch mode (auto / manual / off)
- Ejector tank level alarm (high / overflow)

5. Escalator System

- Number of passengers
- Handrail speed
- Handrail direction
- Step speed
- Step direction
- Bearing temperature
- Running time
- Power consumption
- Running current

6. Lift System

Essential parameters to be monitored

Type	Parameters
Real time	Car Speed
	Car Acceleration/Deceleration
	Car Jerk
	Car Vibration (x, y and z direction)
	Door Speed
	Door Opening
	Door Fully Opened
	Door Closing
	Door Fully Closed
	Stopping Accuracy (Lift levelling accuracy)
Aggregate	Lift Car Mileage
	Lift Car Running Hours
	Lift Car Start/Stop
	Lift Door Opening/Closing Cycles
Events	Lift in Normal mode

Table 16. Essential parameters to be monitored

Additional parameters to be monitored

Type	Parameters
Real time	Hoisting Rope Elongation
	Lift Car Overload
	Lift Car Lighting
	Lift Car Ventilation
	Lift Car Alarm Bell

	Door Protective Device
Faults	Safety Circuit Breakage [NOTE]
	Unintended Car Movement
	Lift Out-of-Service
Events	Lift in Fire Emergency mode
	Lift in Power Failure Emergency Operation

Table 17. Parameters to be monitored

7. Monitoring parameters from Case Study C2

Fire Extinguishers

- Presence of fire extinguisher
- Pressure
- Frontal obstruction
- Presence of foreign objects on fire extinguisher

Exit Lights

- Lamp failure
- Battery lifespan for 1 hour operation

Appendix E: Decision Template for 5-Step SMART Process

The table below summarises the key questions Building Owners and FM Managers should ask and consider when going through each of the 5-step SMART Process.

5-step SMART Process	What Should Building Owners and FM Managers Consider
Step 1 **S**et business objectives and outcomes	• What are my top 3 business objectives? • What do I want to achieve and set as my desired FM outcomes, based on my business objectives and issues faced? • What corresponding KPIs can I set to monitor the progress of my desired FM outcomes? • Which FM services should I prioritise to address the desired FM outcomes? • Can I streamline my current FM processes and procurement framework to meet the identified business objectives and desired FM outcomes? Tool to use Table 1: Template to rank business objectives, set desired FM outcomes, and determine high-priority FM services to focus on
Step 2 **M**ap out Smart FM Solutions as enablers	• What type of "smartness" (Type 1, Type 2, or Type 3) is each high-priority FM service currently at? • What type of "smartness" do I want to achieve for each high-priority FM service? Is it aligned with my business objectives and desired FM outcomes? • What are my pain points and gain points for each high-priority FM service?

5-step SMART Process	What Should Building Owners and FM Managers Consider
	• Do the technology solutions proposed by the FMCs and Service/ Solution Providers fit the requirements to achieve my desired FM outcomes? • How would I like to engage the building occupants and visitors? • Are there FM services that could be integrated to provide multi-functional and enhanced outcomes, e.g. connected lighting systems? • Are there areas where aggregation can be done to achieve economies of scale – at demand and/or supply side? • Is it advantageous to aggregate demand across a portfolio of buildings? Tool to use Table 2: Smart FM Framework References • *Appendix A: List of Smart FM Point Solutions* • *Appendix B: Facilities Management Consortium Operation & Technology Roadmap (COTR)*
Step 3 **A**dopt suitable implementation model	• What is my current working model for existing FM processes and services? • How would I like to work with my FMCs or Service/ Solution Providers? • Which implementation model is more viable at this point to incorporate the various technology solutions identified in Step 2? Or would phased adoption or a variation or hybrid of the implementation models be more applicable? • Does the selected implementation model meet my business objectives, operational priorities and desired FM outcomes?

5-step SMART Process	What Should Building Owners and FM Managers Consider
	• Do I own all the data, regardless of the type of implementation models selected? • Are the system and/or technical requirements specified within my procurement contracts adequate? References • IMDA and PDPC's Trusted Data Sharing Framework *(https://www2.imda.gov.sg/news-and-events/Media-Room/Media-Releases/2019/Enabling-Data-Driven-Innovation-Through-Trusted-Data-Sharing-In-A-Digital-Economy)*
Step 4 **R**eview procurement contract	• What system or technical requirements should I take note of and incorporate within the procurement contract? • Have my technical specifications for the Smart FM solutions taken into consideration the various stakeholders' requirements? • Does my organisation's procurement framework enable an outcome-based contract? • What are the outcome-based measurement, incentives and penalty for each FMC or Service/ Solution Provider? • Can I work together with the FMCs or Service/ Solution Providers to adopt a longer contract term? • Can the FMCs or Service/ Solution Providers optimise delivery of their services and solutions if I aggregate demand across my portfolio of buildings? • Can I aggregate demand within a building and/or across my portfolio of buildings through an Integrated FM contract?
Step 5 **T**rack outcomes and review for continuous improvement	• Has the adopted Smart FM technology solution been well implemented and integrated within my existing FM processes and systems? • Has it addressed the business objectives and desired FM outcomes earlier identified in Step 1?

5-step SMART Process	What Should Building Owners and FM Managers Consider
	• What are the tangible benefits and issues of each adopted solution? • Are there areas for improvement that can be taken into consideration when adopting other Smart FM solutions in the future? • Have the business objectives, desired FM outcomes and high-priority FM services changed? • Are there new technology solutions in the market that can span across various FM services and better meet my needs? • Do the high-priority FM services need to be changed to other types of "smartness"? • Do I need to review and change the outcome-based measurements to better meet the needs/ requirements of various stakeholders?

Table 18. The 5-step SMART process – summary of what Building Owners and FM Managers should consider

S

SET BUSINESS OBJECTIVES & OUTCOMES

**Choose 3 only*

Business Objective	Desired FM Outcome and Corresponding KPI
☐ Cost	*e.g. To reduce operating cost by 10% by 2021*
☐ Manpower (Internal/External)	
☐ System Reliability	
☐ Productivity	
☐ Customer satisfaction	
☐ Security requirements	
☐ Others, please specify:	

M

MAP OUT FM SOLUTIONS AS ENABLERS

**Identify FM solutions (e.g. Company A Solution - video analytics) to meet business objective and outcome*
**Classify FM solutions into Category 1/2/3 (type not in order of merit)*

	FM Services				Towards Aggregation	Implementation across cluster of buildings
	e.g. M&E Functions	*e.g. Security*	*e.g. Cleaning Services*	Others, please specify :		☐ Yes ☐ No
Type 1: Digitalised workflow automation	*e.g. BCA Smart Chiller Portal*	*e.g. Company A Solution*				
Type 2: Optimisation within system only			*e.g. Company B Solution*			
Type 3: Integration/ Synergy across system						

**Classify FM solutions into Model A/B*

Implementation Model to Adopt	FM Solutions
Model A: Integrated Smart FM Solutions *(Each smart FM solution feeds data into one centralised system)* ☐ Solution as a Service via FMC ☐ Acquired & Operated by Building Owner	*e.g. BCA Smart Chiller Portal, Company A Solution*
Model B: Single Smart FM Solutions *(Multiple smart FM solutions with multiple platforms to use)*	

A

R

REVIEW PROCUREMENT CONTRACT

Integrated FM contract for all chosen FM services:
☐ Yes ☐ No, please specify FM services excluded: ________

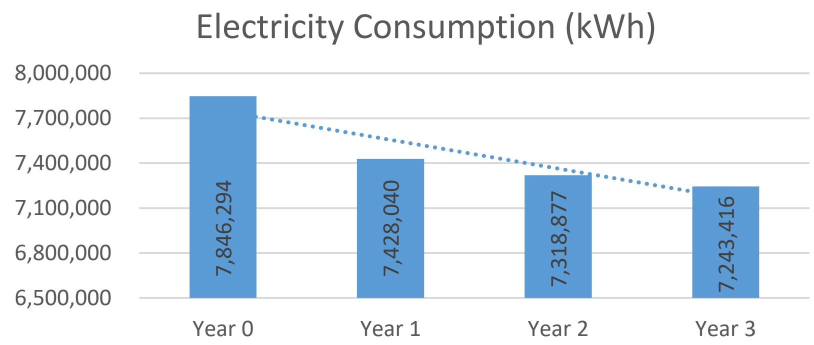
Adopt outcome/performance based contract(recommended)
☐ Yes ☐ No

FM Services Contract Term (recommended 5 to 10 years):
☐ 3+3 ☐ 5+5 ☐ 8 ☐ Others: _______

T

TRACK OUTCOMES AND REVIEW FOR CONTINUAL IMPROVEMENT

**Sample chart to track outcome KPI*
**Repeat this step for remaining business objectives and outcomes*



Status: ☐ Behind ☐ On Track ☐ Ahead

Areas for further improvement/ Proposed recommendation: _____

Any new/emerging smart FM technology: ☐ Yes ☐ No
If yes, please specify: ____

Cost-Benefit Analysis Table

Business Objectives and Desired FM Outcomes	Smart FM Solutions Adopted	Upfront Developmental Costs (A)	Recurring or Yearly Maintenance Costs (B)				Total Cost of Ownership/ Life Cycle Cost (A+B)	Annual Benefit	Total Benefit Over Entire Life Cycle	Feasibility Study Recommendation
		Year 0	Year 1	Year 2	Year 3	Remaining Years				
#1: *e.g. To reduce electricity cost by 20%*	*e.g. Chiller plant optimisation*									
	e.g. Smart lighting with occupancy sensors									
#2: *Please specify*										
#3: *Please specify*										

Appendix F: Essential Smart FM Use Cases

Smart FM leverages technology and data to enhance the efficiency and effectiveness of facility management processes. The table below shows a non-exhaustive list of Smart FM use cases and its definition.

Smart FM Use Cases	Definition
Workflow automation and task assignment	Automated workflow system for FM-related work orders to automate existing work processes and enhanced efficiency of service delivery. Faults and issues are documented, tracked, and routed to the respective service agents.
Energy/power monitoring system	A digital system to monitor, benchmark (actual vs target), and report energy usage of a building broken down by major energy-consuming sub-systems to identify and flag unexpectedly high or low energy usage.
ACMV energy optimisation system	A digital system to monitor, analyse, and modify control settings by taking into consideration of occupancy pattern, weather forecast, etc to achieve the optimum energy usage while maintaining occupant comfort.
Lighting monitoring and control	A digital system to monitor and control the lighting (switch on/off or change levels of light) within specific areas based on inputs such as movement, IR radiation or sound to deliver a comfortable user experience while reducing energy usage.
Renewable energy monitoring and tracking	A digital system to monitor renewable energy generated and consumed on site.
Greenhouse gas (GHG) emissions monitoring and tracking	A digital system that enhances GHG data availability, identifies opportunities for GHG reduction, and supports the achievement of GHG reduction targets over time.
Fault Detection and Diagnostics of ACMV system	A digital system to monitor and automate the process of detecting faults and suboptimal performance of building ACMV systems. The solution usually provides several possible causes or recommendations for correcting each fault.
Fault Detection and Diagnostics of lifts, escalators, or other equipment	A digital system to monitor and automate the process of detecting faults and suboptimal performance of lifts, escalators, and other equipment.
Water monitoring & leakage detection	A digital system to monitor, benchmark (actual vs target), and report water usage of a building to identify and flag unexpectedly high or low water usage.
Water tank level monitoring	A digital system to monitor the levels of water tanks remotely without any physical human efforts such as manual meter reading and assessments.
Indoor Air Quality monitoring	A digital system to monitor, benchmark, report, and control the indoor air quality of the regularly occupied spaces to empower occupants & FM team about their environmental quality.
Thermal comfort monitoring	A digital system to monitor thermal comfort parameters (e.g. dry-bulb temperature and relative humidity) in the regularly occupied spaces that can be used as feedback for facility manager and users to take appropriate actions.
Smart Toilet	An advanced toilet system equipped with electronic features and technologies designed to enhance comfort, hygiene, and convenience.
Space Optimisation	A digital system to track and reports space utilisation to help FM teams optimise space use and/or adjust maintenance services.
Remote tree monitoring	A digital system to monitor any sign of tree failures in the urban area (e.g. using electronic tilt sensor).
Bin status monitoring	A digital system that tracks the waste fill levels of bins to optimise collection schedules and improve the efficiency of manpower and deployment
Fire alarm monitoring	A digital system to monitor any sign of temperature spike to trigger alert for inspection.
Smart Fire Safety and Emergency Platform	An integrated digital system designed to enhance fire safety and emergency response through advanced technology (e.g., to electronically monitor and manage the operational status of fire extinguishers and exit lights)
Incident monitoring	A digital system that uses tools like video analytics to detect and identify incidents, enabling timely response, impact mitigation, and analysis to prevent future occurrences.
Tenancy management	A digital system to digitalise leasing processes for better control and management of rental properties under its portfolio.
Foot traffic monitoring	A digital system to monitor the number of people who walk into or around a given area at a specific time (e.g. using wifi analytics) for business owners and retail store owners to evaluate or measure the effectiveness and value of a commercial facility.
Cleaning Robot	An autonomous or semi-autonomous machine designed to perform cleaning tasks without the need for constant human intervention.
Security Robot	An autonomous or semi-autonomous machine designed to enhance security by monitoring and patrolling specific areas.
Drone for Facade and/or Rooftop Inspection	An unmanned aerial vehicle (UAV) specifically designed to inspect and assess the condition of building facades and rooftops.
Condition-based Maintenance	A proactive maintenance strategy that involves performing maintenance tasks based on the actual condition of equipment or systems, rather than on a predetermined schedule.

Table 19. List of essential Smart FM use cases