



# **Project Report**

## **Program 3**

Productivity through Innovation

### **Project 3.48**

Sustainable Asset Management – Selecting optimal maintenance strategies based on multi-criteria decision making

**Subtopic:** Developing a total building maintenance framework through benchmarking

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## Executive summary

In order to identify the best public building maintenance practices, a literature review was conducted to identify the public building maintenance schemes/initiatives/frameworks in a number of developed economies, including the United States, Hong Kong and the UK. In addition, the maintenance frameworks and asset management documents from a Queensland Department are also reviewed to outline opportunities and options for improving the decision making with regards to maintenance of office buildings.

The findings are that: 1) There is a suite of documents available on the Queensland Department of Housing and Public Works which clearly articulates the maintenance and asset management requirements; 2) The review indicates that maintenance management is in a transition from prescriptive based specification towards a performance-based evaluation; 3) It is beneficial to provide a detailed classification of the serviceability of the government office because different levels of serviceability will have different maintenance requirements and different levels of serviceability should be evaluated based on different sets of metrics; 4) There is a clear trend that capturing various types of information and knowledge in maintenance using information technology, such as the building information modelling, will help achieve making more effective decisions.

A total building maintenance framework (see Figure 1) is developed to help demonstrate what elements should be included in the performance-based evaluation. There are eight elements that should be considered, including: 1) strategy and program; 2) cost; 3) occupant satisfaction; 4) work execution; 5) environmental sustainability; 6) quality; 7) health and safety; and 8) staff requirement. A survey that uses these eight elements is developed as an approach to support the Queensland department for the adoption of improvements to building maintenance decisions.

**Keywords:** Building maintenance; Framework; Performance-based evaluation; Government offices

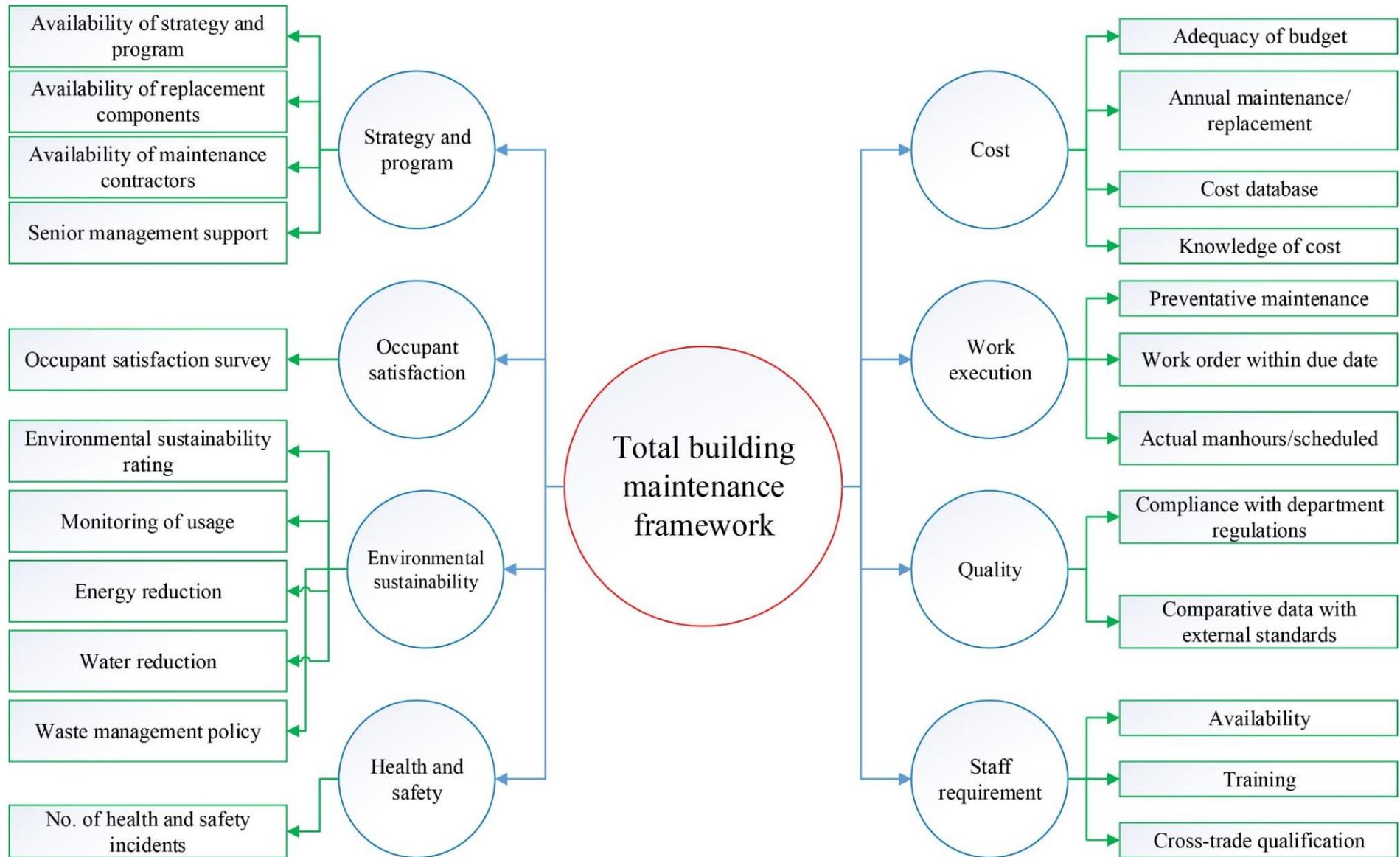


Figure 1. The total building maintenance management framework

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## **1. Introduction**

Buildings have been considered as one of the most valuable assets of a nation to provide people with shelter and facilities for work and leisure. As time passes by, maintenance of buildings becomes an invaluable process in retaining the value and quality of a building (Vijverberg, 2002). Building maintenance accounts for over half of the total output of the building industry (Wordsworth, 2001). In Britain, building maintenance activities have reached a level of 50 per cent of all annual construction activities (Kherun et al., 2002). In Hong Kong, the gross value of general trades such as decoration, repair and maintenance, and construction work at minor work locations has increased over the past five years. Governments across the world have considerable expenditure directed toward maintenance and operation projects (Al- Arjani, 2002).

It is argued that there should exist a comprehensive, objective, reliable and practical performance evaluation model for maintenance projects. However, measuring maintenance projects is a complex task and there is a lack of common base for comparison. Wood (2005) claimed that building maintenance is even under-researched and an investigation into the project success for building maintenance projects can help set a benchmark for future projects.

This study aims to provide a review of literature on benchmarking the performance in the area of building maintenance practices for a Queensland department against other best practices from developed economics, such as the United States, Hong Kong and the UK. The results of generating an objective performance-based evaluation criteria will also be provided from this study.

## **2. Building maintenance in the United States**

### **2.1 Introduction**

The government of the United State of America (USA) includes probably the largest set of organizations that are implementing a comprehensive performance-based approach program for the maintenance management of public facility. Some notable milestones include:

- In 1993, Congress passed a law titled “The Performance and Results Act, 1993”. It requires all government agencies to prepare Strategic Plans that also include a Performance Plan.
- In 2004, the Executive Branch of the US government issued an Executive Order detailing how government assets will need to be managed, including reporting on key performance indicators on a quarterly basis.

- US government agencies are assembling the current measures of performance that are used to assess the performance of their constructed assets. A report has been published by the Federal Facilities Council detailing those Key Performance Indicators (KPIs). The report is available at: <http://www.mass-plc.com/documents/f2ebb659-7e66-4fb9-ac60-8a5a27738e7c.pdf>
- One most recent development is that the US General Services Administration (GSA) is requesting that the software applications that it will use should be IAI – IFC compliant (International Alliance for Interoperability – Industry Foundation Class). This again will have a major impact on how building information and data will be classified and organized.

## 2.2 Evaluation criteria

The U.S. government uses the ASTM E1670-95a: Standard Classification for Serviceability of an Office Facility for Management of Operations and Maintenance to estimate the serviceability of an existing facility, which is the capability of an office facility to meet certain possible requirements for maintenance. A summary of the ASTM E1670-95a maintenance framework is shown in Figure 2.

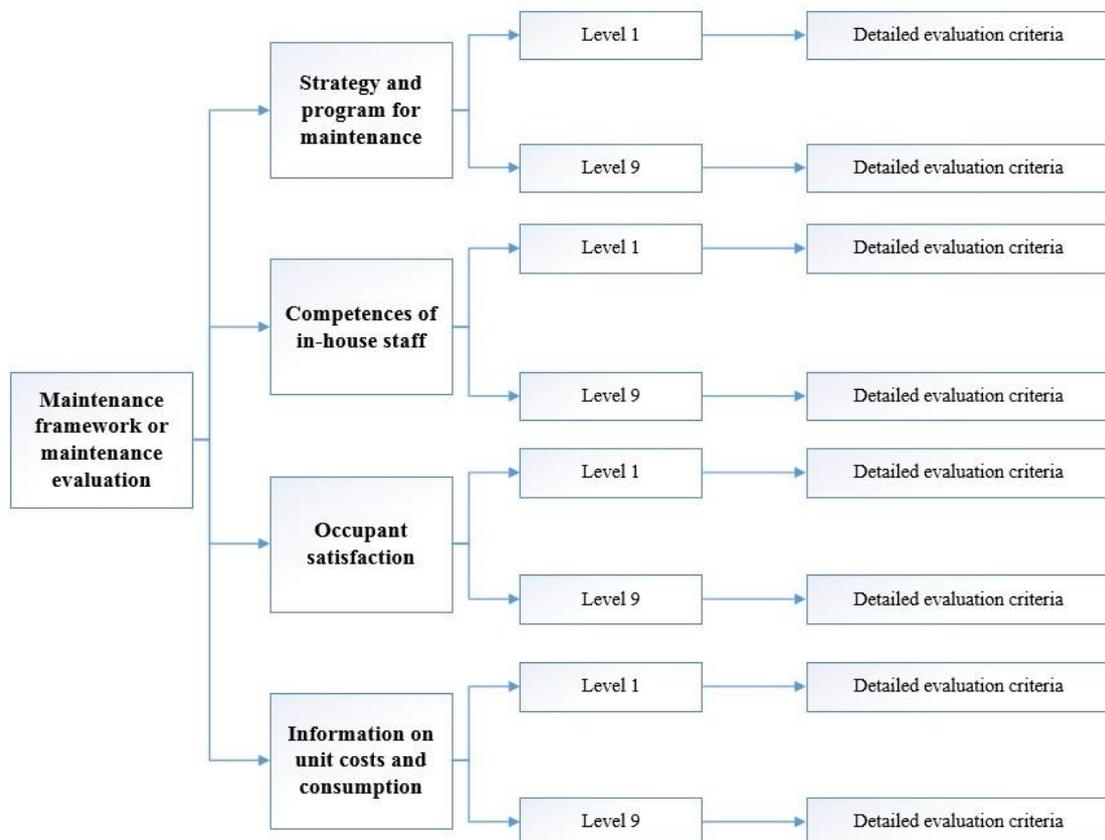


Figure 2. A summary of the ASTM E1670-95a maintenance framework of office

Table 1. Classification of Serviceability based on Strategy and program of maintenance

<b>Strategy and program of maintenance</b>	
<b>Requirement Level – 9</b>	
Level of maintenance	Require buildings to be maintained and operated at a high level, helping occupants to be fully productive within their work environment.
Tolerance for occupant loss of productivity	Any loss of productivity due to breakdown of building services cannot be tolerated.
Availability of support services	Need highly organised and responsive support service available to supplement in-house staff.
<b>Requirement Level - 7</b>	
Level of maintenance	Require buildings to be operated and maintained at a higher than average level.
Tolerance for occupant loss of productivity	Breakdowns must be rare, having negligible effect on productivity, and be repaired in hours, not days.
Availability of support services	Require readily available outside support services to support in-house maintenance staff.
<b>Requirement Level - 5</b>	
Level of maintenance	Require buildings to be operated and maintained in a manner acceptable to the typical occupant in that locality.
Tolerance for occupant loss of productivity	Breakdown of building services can be tolerated if rarely occurring, having minor effect on productivity, causing only minimal disruption and requiring same-day repair.
Availability of support services	Require support services to be available.
<b>Requirement Level - 3</b>	
Level of maintenance	Require minimal operation and maintenance.
Tolerance for occupant loss of productivity	Even lengthy or disruptive breakdown need not be costly for the organisation.
<b>Requirement Level - 1</b>	
Level of maintenance	Very few occupants.
Tolerance for occupant loss of productivity	Little consequence if frequent or major disruptions.

The U.S Department of Energy has published a standard set of metrics to evaluate the performance of commercial buildings, including maintenance. The metrics can be used for comparative performance analysis between existing buildings and industry standards.

The set of metrics is mainly related to the evaluation of maintenance cost. Please see the following Table 2 for some examples of the detailed cost metrics.

Table 2. The metrics used by the U.S. Department of Energy to evaluate cost of maintenance

Items	Measurements
1. Building Maintenance	
1.1 Preventative Maintenance	Cost/ft <sup>2</sup> ; # of PM items; hours for PM; jobs/year
1.2 Work Order or Service Calls	
Type of work order	% by type
Work order hazardous material use	Volume/ft <sup>2</sup>
Work order materials inventory	Cost/ft <sup>2</sup>
1.3 Diagnostic maintenance cost	Cost/time; hours/time
1.4 Special project maintenance	Cost/ft <sup>2</sup> ; hours/service; jobs/year
1.5 Emergency maintenance cost	Cost/time
2. Janitorial service cost	Cost/ft <sup>2</sup> ; hours/service; jobs/year
3. Grounds maintenance cost	Cost/ft <sup>2</sup> ; hours/service; jobs/year

### 3. Building maintenance in Hong Kong

#### 3.1 Introduction

The building maintenance scheme provides a comprehensive one-stop maintenance service over a 5-year period. The purpose of the scheme is to carry out inspection in order to prevent dilapidation, eliminate health and safety hazards, minimize breakdowns and avoid unnecessary expenses on major corrective maintenance.

#### 3.2 Evaluation criteria

A detailed list of the evaluation factors in the Hong Kong building maintenance scheme is listed in Table 3. The evaluation criteria include:

**Tangibles:** these relate to the facilities, equipment and all other necessary resources, e.g., sufficient manpower to complete handy repair and works order items, which the contractor will allocate for the implementation of the scheme.

**Reliability:** this is the ability of contractor personnel to perform agreed tasks up to the client's standard and within the agreed time schedule.

**Responsiveness:** refers to the willingness of the contractor personnel to provide prompt services to the tenants and the internal customer of the building maintenance scheme, i.e., the owner's front-line representative.

Table 3. The evaluation criteria in the Hong Kong Building Maintenance Scheme

Tangible	Sufficiency and adequacy of replacement components and repair equipment
	Provide sufficient manpower to complete the works order
	Availability on ancillary equipment and tools
Reliability	Conformance to owners' requirements on supply quality
	Provide their services at the time they promise to do so
	Progress of works (handy-work items)
	Progress of works (work order items)
	Competence of the work coordinators or fitters
	Competence of assistance services manager/site agent
	Site safety implementation
Responsiveness	Give prompt services to tenants
	Timely and quality submission of required documents and information
	Willingness to help tenants
Assurance	Courteous with tenants or owner's frontline representatives
	Have knowledge to answer tenants or owner's frontline representatives' enquiries
	Assuring the quality of works up to standard
	Cooperate with owner's frontline representatives to solve problem
	Cooperate with members of Management Advisory Committee in different estates
	Cooperate with Housing Managers
Empathy	Operating hours convenient to tenants
	Tidiness after repair works
	Enhanced services protection work

**Assurance:** this includes the knowledge and courtesy of contractor personnel to handle enquiries and the ability to inspire trust and confidence to various stakeholders, such as the Management Advisory Committee in each estate and the Housing Managers in the owner's organization.

**Empathy:** this relates to caring, understanding and sharing of feelings of the customers, e.g., tenants and the owner's frontline representative.

## 4. Building maintenance in UK

### 4.1 Introduction

Building maintenance management in UK is regulated by different councils. The maintenance evaluation relies on the owner's consideration. However, it is centrally guided by the British Standard (British Standard Institution, 1986, 1992, 2012): Guide to facilities maintenance

management. The British Standard Institution recommends the use of tools such as value management, the EFQM Excellence Model, balanced scorecards and benchmarking to assist in the measurement of performance and in indicating where improvement is required.

#### **4.2 Evaluation criteria**

The commonly adopted methods of measurement include:

- Compliance. Services will be delivered in accordance with relevant statutory legislation and appropriate guidelines including British Standards, Manufacturers Recommended Instructions, IEE Recommendations, Gas Safety Regulations, Construction (Design Management) Regulations including Duties of the Client, Health & Safety at Work Act and Other relevant statutory legislation.
- Value for money. Random sample checks will be made on 20% of all maintenance works carried out by contactors. In addition, all works over £2,000 in value will also be subject of checks. The check will include a desk top review of invoices to check that the amounts charged are consistent with the tendered rates and the hours charged are reasonable for the type of work. A site visit will also be arranged to inspect the work.
- Quality of service. The client will monitor contractors/consultants' performance annually or as required against quality indicators including timeliness of response, health & safety, safeguarding and quality of works on site.
- Customer satisfaction. The client will appoint a dedicated liaison officer for each building who will undertake regular liaison with the building consistent with the scale and complexity of works being undertaken. They will undertake site visits, attend meetings as required and will seek feedback from the school and keep records of customer satisfaction on a job by job basis.

The BSI 8210-2012: Guide to facilities maintenance management is available from:  
<https://www.scribd.com/document/274163717/BS-8210-2012>

### **5. The Queensland Department of Housing and Public Works' frameworks related to maintenance of government buildings**

The frameworks related to maintenance of government buildings published by the Queensland Department of Housing and Public Works include the:

- *Maintenance Management Framework*

<http://www.hpw.qld.gov.au/FacilitiesManagement/BuildingMaintenance/Pages/Default.aspx> )

- *Building Asset Performance Assessment Framework* and the asset management frameworks which are available at:

<http://www.hpw.qld.gov.au/FacilitiesManagement/BuildingFrameworks/Pages/Default.aspx>.

Please refer to Table 4 for more information.

Table 4. The factors considered in the building maintenance frameworks and polices from QDHPW

Tier 1 factors	Tier 2 factors	Tier 3 factors	References
Asset Performance	<ul style="list-style-type: none"> <li>• Building condition assessment</li> <li>• Asbestos surveys<sup>a</sup></li> <li>• Building asset register</li> <li>• Building reviews<sup>b</sup></li> <li>• Risk management audits</li> <li>• Data collection for life-cycle planning</li> <li>• Energy management audits</li> <li>• Engineering investigations<sup>c</sup></li> <li>• Environmental audits</li> <li>• Water management audits</li> </ul>	<p><sup>a</sup>asbestos audits; asbestos inspections.</p> <p><sup>b</sup>building codes audits; fire safety audits, town planning code audits; health &amp; amenity audits; functionality audits; utilisation audits; postoccupancy evaluations.</p> <p><sup>c</sup>geotechnical investigations, structural integrity investigations, electrical investigations.</p>	<p><a href="http://www.hpw.qld.gov.au/SiteCollectionDocuments/SAMFAra.pdfv">http://www.hpw.qld.gov.au/SiteCollectionDocuments/SAMFAra.pdfv</a></p>
Environmental Sustainability	<ul style="list-style-type: none"> <li>• Heating, ventilation and air conditioning systems audit</li> <li>• Building sealing audit</li> <li>• Glazing and shading audit</li> <li>• Energy Efficient Control systems audit</li> <li>• Waste, energy and water monitoring equipment audit</li> </ul>		<p><a href="http://www.hpw.qld.gov.au/FacilitiesManagement/BuildingFrameworks/SAMF/Pages/Guidelines.aspx">http://www.hpw.qld.gov.au/FacilitiesManagement/BuildingFrameworks/SAMF/Pages/Guidelines.aspx</a></p>
Lifecycle Maintenance Costs	<ul style="list-style-type: none"> <li>• Agency management/administration costs<sup>d</sup></li> <li>• Condition assessment costs</li> <li>• Planning maintenance costs<sup>e</sup></li> <li>• Unplanned maintenance costs</li> </ul>	<p><sup>d</sup>Computerised maintenance systems</p> <p><sup>e</sup>Preventative; statutory; condition-based</p>	<p><a href="http://www.hpw.qld.gov.au/SiteCollectionDocuments/SAMFLcp.pdf">http://www.hpw.qld.gov.au/SiteCollectionDocuments/SAMFLcp.pdf</a></p>

Tier 1 factors	Tier 2 factors	Tier 3 factors	References
Natural Disasters Mitigation	<ul style="list-style-type: none"> <li>Land use planning assessment</li> <li>Engineering<sup>f</sup> assessment</li> <li>Building services assessment</li> <li>Building codes and standards compliance</li> <li>Building resilience assessment</li> </ul>	<sup>f</sup> Civil and structural engineering	<a href="http://www.hpw.qld.gov.au/SiteCollectionDocuments/SAMFMind.pdf">http://www.hpw.qld.gov.au/SiteCollectionDocuments/SAMFMind.pdf</a>
Government Building Management	<ul style="list-style-type: none"> <li>Continued Compliance with Government priorities, strategies, policies<sup>g</sup> and agency policies.</li> <li>Assessment of suitable suppliers of maintenance work</li> </ul>	<sup>g</sup> Examples: State Procurement Policy; Local Industry Policy; State Gov't Building & Construction Contracts Structured Training Policy; Indigenous Employment Policy for Qld Gov't Building & Civil Construction Projects	<a href="http://www.hpw.qld.gov.au/SiteCollectionDocuments/SAMFBm.pdf">http://www.hpw.qld.gov.au/SiteCollectionDocuments/SAMFBm.pdf</a>
Risk Management	<ul style="list-style-type: none"> <li>Risk management plan audit<sup>h</sup></li> </ul>	<sup>h</sup> Identification, analysis, evaluation & treatment of risks	<a href="http://www.hpw.qld.gov.au/SiteCollectionDocuments/SAMFRm.pdf">http://www.hpw.qld.gov.au/SiteCollectionDocuments/SAMFRm.pdf</a>
Value Management	<ul style="list-style-type: none"> <li>Stakeholder workshop to achieve best</li> </ul>		<a href="http://www.hpw.qld.gov.au/SiteCollectionDocuments/SAMFVm.pdf">http://www.hpw.qld.gov.au/SiteCollectionDocuments/SAMFVm.pdf</a>

	value for money for maintenance work		
Workplace Maintenance Health & Safety	<ul style="list-style-type: none"> <li>• Health &amp; safety risk audits</li> </ul>	<sup>i</sup> Identification & implementation of health & safety risk procedures	<a href="http://www.hpw.qld.gov.au/SiteCollectionDocuments/SAMFWhs.pdf">http://www.hpw.qld.gov.au/SiteCollectionDocuments/SAMFWhs.pdf</a>
Post Occupancy Evaluation	<ul style="list-style-type: none"> <li>• Post-occupancy research evaluation<sup>j</sup></li> </ul>	<sup>j</sup> Functional, technical & environmental, economic and symbolic performance.	<a href="http://www.hpw.qld.gov.au/SiteCollectionDocuments/SAMFPoe.pdf">http://www.hpw.qld.gov.au/SiteCollectionDocuments/SAMFPoe.pdf</a>

## 6. Conclusions

The findings from the review at the time of this study is that the suite of documents available on the Queensland Department of Housing and Public Works clearly articulates the building maintenance and asset management frameworks and requirements. Agencies from other developed economies rely heavily on outsourcing the work. For example, the U.S government relies on the standards published by the American Society for Testing and Materials (ASTM) and Government Services Agency (GSA) for establishing building maintenance standards. However, these standards were not clearly communicated with the public through their website or other communication methods.

In addition, the review indicates that maintenance management is in a transition from prescriptive based specification towards a performance-based evaluation. The U.S. and Hong Kong have developed detailed set of metrics to evaluate building maintenance work. The traditional way is a prescriptive standard based on preventive maintenance of the mechanical systems. The standard implies the appointment of a facility manager responsible for administering all necessary preventive and breakdown maintenance activities to maintain the building at safe and sustainable condition. The standard does not indicate performance levels by which the building performance may be monitored; furthermore, the standard does not allow any consideration of the performance level of building by the owner of the facility.

It is also beneficial to separate the evaluation criteria for different levels of building maintenance. For example, the American Standards classify 9 levels of building maintenance performance levels. The owners may select the correct levels in order to identify the appropriate evaluation criteria. This is useful to maintain a high level of maintenance efficiency.

This review also finds that improving the operations of building maintenance requires many supportive facilities for both management and technology aspects. How to successfully capture these information in information technology is a research trend at the time of this study. This will help maintenance teams learn from previous experience and trace the full history of a building element and all affected elements by previous maintenance operations. It is recommended the relevant Queensland Departments consider this research review report and take actions towards identifying and capturing building maintenance data in the most appropriate data format for decision making.

Figure 1, as the total building maintenance framework identified in this study, covers eight general assessment areas and may be used as the basis to develop the agency-specific building maintenance framework in the future.

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