

Lifecycle Cost Modelling: A Data-Driven Approach to Extending the Operational Life of Healthcare Facilities

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Covaris Pty Ltd
Suite 2 Level 4, 410 Chapel Road
Bankstown NSW 2200
AUSTRALIA

Seyed Safi
s.safi@covaris.com.au



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Abstract:

Extending the operational life of hospital facilities requires data-driven assessment and strategic asset management. A multidisciplinary audit was conducted across several hospital buildings to evaluate the condition of infrastructure assets and identify requirements for sustaining operational reliability over extended timelines. The assessment encompassed mechanical, electrical, fire, hydraulic, façade, roofing, ICT, and other critical systems. Historical asset data, on-site inspections, and stakeholder consultations were used to validate asset information, assess asset condition, and identify maintenance, compliance, and safety issues.

An updated asset register of more than 10,000 assets was developed, incorporating newly identified assets and revised condition ratings. A bottom-up lifecycle cost model was subsequently applied to forecast maintenance, refurbishment, replacement costs over a 20-year horizon, as well as the necessary repairs, replacements, or upgrades associated with the recommended remedial actions for the identified issues. The findings establish an evidence-based framework to prioritise maintenance, plan renewals, and optimise lifecycle management, supporting the sustained reliability and resilience of hospital infrastructure.

Keywords:

Lifecycle Cost Modelling, Asset Lifecycle Management, Healthcare Facility Asset Management, Preventative Maintenance, Corrective Maintenance, Asset Refurbishment, Asset Replacement, Condition Assessment, Asset Register Validation, Bottom -Up Cost Modelling

1 Introduction

Healthcare facilities rely on the continuous functionality of their physical infrastructure to ensure safe and reliable clinical service delivery. As hospitals age, the need for accurate lifecycle forecasting and proactive asset management becomes increasingly critical. Infrastructure systems - including mechanical, electrical, fire safety, hydraulic networks, ICT infrastructure, building fabric, façade systems, and roofing - must be systematically maintained to mitigate risk, uphold compliance, and avoid disruption to essential healthcare operations.

This paper presents a comprehensive, data-driven methodology for extending the operational life of hospital facilities. Through a detailed audit, validation of asset information, asset condition assessment, and bottom-up cost modelling, the approach provides healthcare organisations with reliable forecasts of long-term maintenance and renewal needs, and addresses identified issues across the facility.

2 Cost Modelling Methodology

Using data from the site audit, a bottom -up Asset Lifecycle and Maintenance Cost Model was developed. The model is built by calculating maintenance and lifecycle costs for the validated asset register, followed by estimating the cost of proposed works to address chronic issues identified through site visits, consultation with the hospital’s asset management team, and reviews of prior condition assessments.

Figure 1 summarises the model’s cost categories:

1. Preventative Maintenance
2. Corrective Maintenance
3. Asset Replacement
4. Asset Refurbishments
5. Corrective Actions for Remediation of Known Issues.

Figure 2 shows the process for calculating cost components 1 to 4.

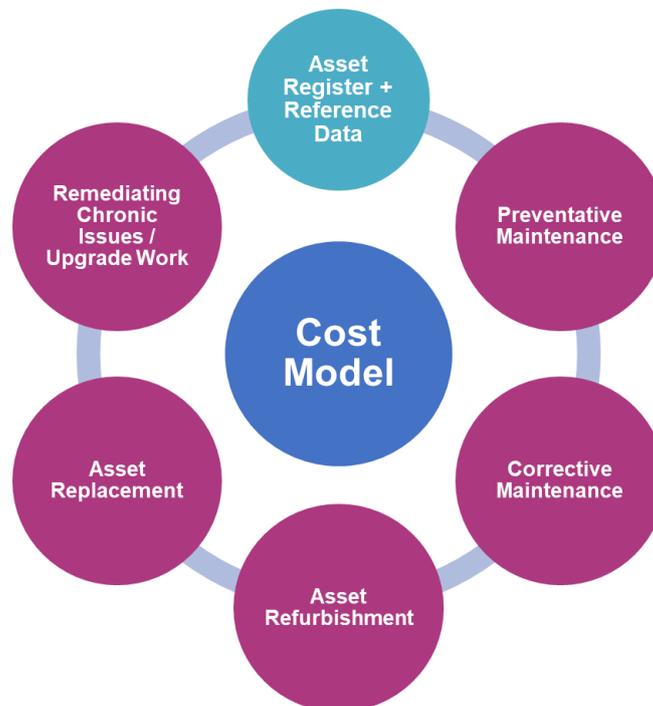


Figure 1 Cost Model Elements

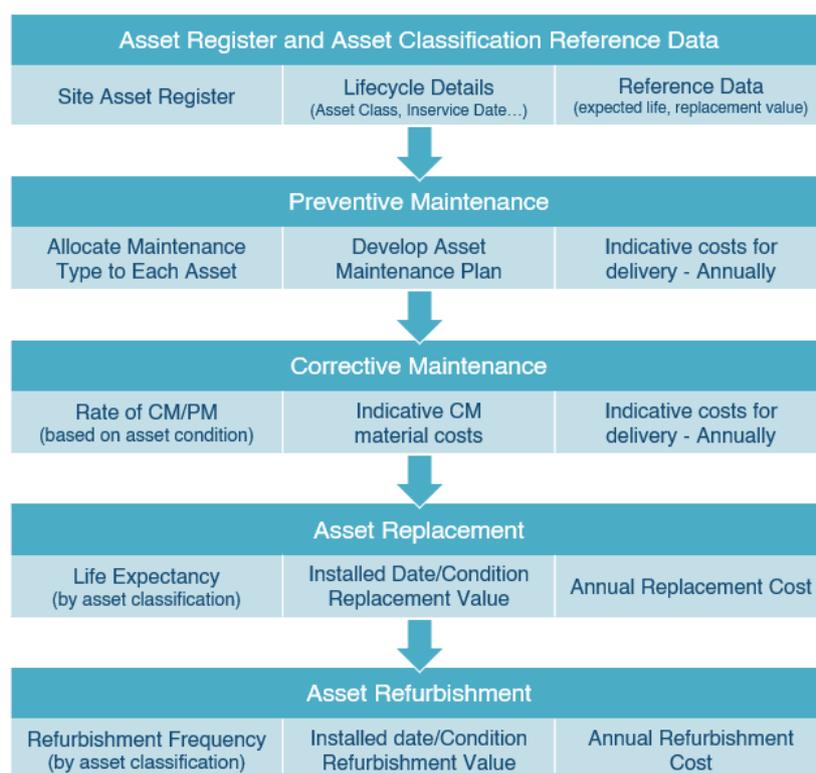


Figure 2 Asset Maintenance and Life Cycle Costs Modelling Process

2.1 Asset Register and Asset Classification Reference Date

The first step in the cost modelling of a healthcare facility is to identify the list of assets which is used for the bottom-up modelling approach. The required asset data are:

1. Asset Details: asset id, asset name, asset classification as a minimum plus additional asset details if available (e.g., manufacturer name, model number);
2. Asset Lifecycle Details: in service date, purchase cost / replacement value; and
3. Asset Condition Assessment (if available): observation date, Condition Rating, Current Usage, Operating Environment, Criticality. If asset conditions were not available, asset condition was assigned based on the age of the facility.

An asset reference data library is required for building and facility assets to enable the modelling of maintenance costs for healthcare facilities. The reference data have been developed for all asset classifications used in the hospital's asset register. This information drives the calculation of maintenance costs and includes the following:

1. Identifying the maintenance strategy for assets with applicable asset classifications. All assets will be identified as requiring planned maintenance or unplanned maintenance.
2. Price Book: This important reference data provides the current replacement value for assets. If the healthcare facility asset register has accurate purchase cost/replacement value, these values will be used in the calculation of refurbishment and replacement costs. If cost data is not available, the average price from the price book for the applicable asset classification will be used.
3. Life Expectancy (years): Provides the expected life by asset classification. Assets will be replaced when they reach the end of their expected life (see Table 1).
4. Planned Refurbishment (years): The expected frequency of the refurbishment by asset classification (see Table 1).
5. Planned Refurbishment (%): The percentage of the asset cost required for the planned refurbishment (see Table 1).

Asset Classification Name	PM Strategy Name	Life Exp. (yrs)	Refurb. Freq. (yrs)	Refurb. Cost as a % of Replacement Cost	Library Minimum Cost	Library Maximum Cost	Library Average Cost
Chilled Water Pumps	Centrifugal Pump	15	5	25%	\$6,118	\$19,467	\$12,793
Chillers	Screw Chiller	15	10	30%	\$25,917	\$833,919	\$346,858
Cooling Towers	Cooling Tower	20	10	30%	\$51,468	\$261,000	\$172,981
Distribution Boards	Distribution Board	20	10	20%	\$7,930	\$96,200	\$24,175
Goods Lifts	Lift	25	10	20%	\$321,103	\$403,245	\$362,174
Fire Doors	Fire Doors	20	5	5%	\$3,018	\$8,223	\$3,945
Fire Hose Reels	Fire Hose Reel	10	5	20%	\$711	\$839	\$775

Table 1 Sample Asset Reference Data Library

2.2 Estimated Cost of Preventative Maintenance

The first cost component in the model is developing the bottom-up budget for preventative maintenance. This includes calculating the preventative maintenance cost for all maintainable assets using the following steps:

1. Allocate Maintenance Type to each asset: At the end of this stage, each asset will have a type of maintenance allocated (planned or unplanned) based on the asset reference data library.
2. Develop Asset Maintenance Plan: This stage involves developing an Asset Maintenance Plan for all assets identified with a planned maintenance type, based on the developed Planned Maintenance Service Plans. The maintenance service plans are aligned with the statutory maintenance requirements for the applicable asset classification. At the end of this stage, the Asset Maintenance Plan developed will contain a detailed maintenance schedule and resource requirements.
3. Indicative Costs for PM Delivery: Develop an annual PM maintenance cost forecast for all assets in the asset register. This includes calculating the annual PM delivery cost based on estimated task duration and the hourly rate of the required resources. PM delivery costs also include work quality checks, administrative support, supervisor oversight, and cost of spare parts.

2.3 Expected Cost of Corrective Maintenance

The second cost component in the model is developing the budget for corrective maintenance, which is estimated based on the asset condition across the site using the following steps:

1. Rate of CM/PM: Corrective Maintenance (CM) annual costs are estimated as a percentage of calculated Preventive Maintenance (PM) costs, based on asset condition. Table 2 shows the remaining life and the ratio for CM costs as a percentage of PM costs based on the asset condition.
 - a. The CM/PM labour hourly rate is 125% (on average, the hourly rate for corrective work is 25% higher than the preventive work hourly rate).
2. Indicative CM Material Costs: The estimated cost of materials for CM work is estimated at 20% of the CM labour hour costs.

- Indicative costs for delivery: Develop an annual corrective maintenance cost forecast for all assets in the site-specific asset register. CM delivery costs include trade resource hours, work quality checks, administrative support, supervisor/building manager, and spares cost.

Condition	Remaining Life (%)	CM to PM Ratio (%)
Excellent	95	10
Good	75	44
Fair	50	58
Poor	20	87
Very Poor	5	116

Table 2 Remaining Life and Rate of CM/PM Cost

2.4 Life Cycle Replacement

The third cost component in the model is the Life Cycle Replacement cost which is calculated for all assets included in the site-specific asset register based on the following steps:

- Life Expectancy (years): Expected life of each asset is identified based on the asset classification. The expected life for the applicable asset classification is identified in the asset reference data library.
- Installed date and Replacement Value: Identify the installed date and asset replacement value from the asset register. If the data is not available, identify the installed date by consulting healthcare facility asset managers or the age of the facility. The replacement value can be estimated based on the asset classification and the replacement value for the applicable asset classification as identified in the asset reference data library. If the healthcare facility asset register has accurate purchase cost/replacement value, these values will be used in the calculation of refurbishment and replacement costs.
- Annual Replacement Cost: Develop an annual life cycle replacement cost forecast for the life of the assets for the site-specific asset register. For the 25-year Cost Modelling, assets may be replaced multiple times based on their expected life.

2.5 Life Cycle Refurbishment

The last cost component in the model is the Life Cycle Refurbishment cost which is calculated for all assets included in the site-specific asset register based on the following steps:

- Refurbishment Frequency (years): The refurbishment frequency of each asset is identified based on the asset classification as identified in the asset reference data library.
- Installed date / Refurbishment Value: The installed date is identified from the asset register, if available. If the data is not available, the installed date is identified in consultation with healthcare facility asset managers or the age of the facility. The refurbishment value for each asset is a percentage of the replacement value of the asset based on the applicable asset classification as identified in the asset reference data library.
- Annual Refurbishment Cost: Develop an annual lifecycle refurbishment cost forecast for the site-specific asset register. For the 25-year Cost Modelling, assets may be refurbished multiple times based on their refurbishment frequency.

2.6 Remediating Chronic Issues / Upgrade Work

The final component of the cost model involves estimating the cost of proposed works to remediate identified chronic issues and undertake the work required to extend the operational life of the building or facility. These issues are identified through the following activities:

- Building audits to identify non-compliance or other issues
- Workshops with the healthcare facility's asset management team

- Reliability analysis of work order history records from the healthcare facility’s Enterprise Asset Management System
- Review of previous condition assessment reports

Figure 3 shows the methodology for developing this cost element. As part of this component, known issues are itemised, and a top-level cost estimate is developed to support budgeting for the specified issues. In addition to the estimated cost to remediate each issue, a priority level and recommended start date are assigned in consultation with the healthcare facility asset management team. An example of this type of work is the remediation of mould in sections of the hospital’s HVAC ductwork or upgrades to ICT infrastructure that no longer complies with current standards.

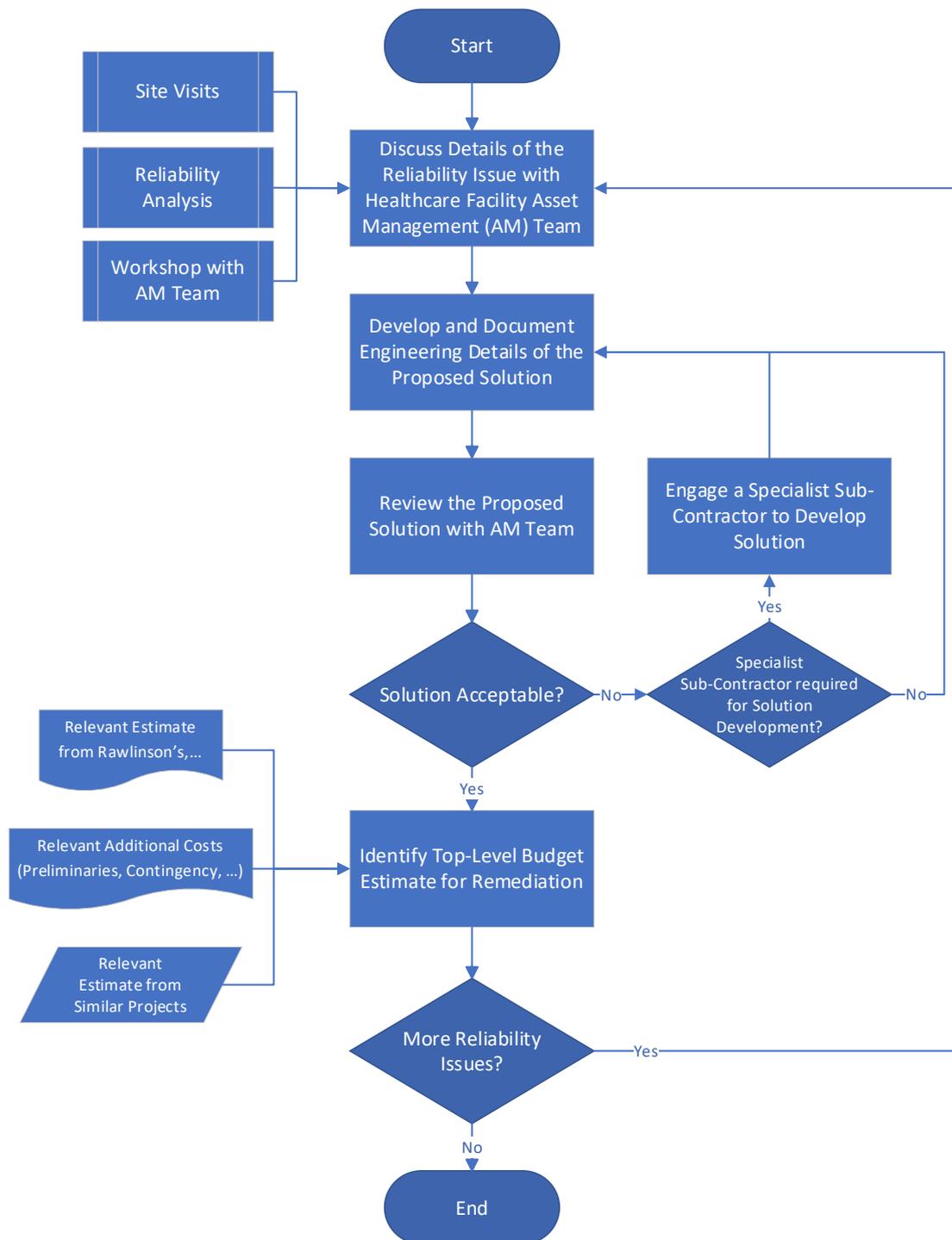


Figure 3 Methodology for Developing Costed Solutions for Chronic Issues

2.6.1 Action Priority

Each identified issue was risk-ranked and assigned a corresponding solution. The priority level of each solution was determined based on the associated risk rating, which in turn established the required timeframe for implementation. The definitions for each priority category are provided in the table below.

Risk Rating	Priority Rating	Timeframe	Description
Extreme	1	Immediate	Immediate action required
High	2	1-2 Years	Senior management attention required
Medium	3	3-4 Years	Management responsibility to be specified
Low	4	5-6 Years	Managed by asset management routine maintenance

Table 3 Action Priority Ranking

2.6.2 Project Overheads and Project Staging

The lifecycle stages for the major projects are:

- Stage 0 – Plan
- Stage 1 – Develop
- Stage 2 – Prove
- Stage 3 – Procure
- Stage 4 – Implement
- Stage 5 – Measure

Due to the scale of several remediation projects, major works were staged for completion over multiple years. These projects will be delivered over five years to ensure controlled sequencing and minimal operational disruption. The staging for a sample project is outlined below.

- Year 1 (2026–27): Plan (Early investigation) and Develop (Feasibility) - 0%
- Year 2 (2027–28): Prove (Business case) and Procure (Tender) - 2.5%
- Year 3 (2028–29): Implement (Design + Early Construction) - 30%
- Year 4 (2029–30): Implement (Main Construction) - 65%
- Year 5 (2030–31): Measure (Commissioning) - 2.5%

This five-year funding model provides a structured approach to delivering complex projects while maintaining continuous operation of the healthcare facility. Table 4 provides the percentage of gross project cost allocated to each overhead cost component.

Overhead Cost Component	Overhead	Project 1 – ICT Infrastructure Upgrade	Project 2 – Cooling Towers Upgrade
	Gross	\$2,500,000	\$832,500
Preliminaries + supervision	21%	\$525,000	\$174,825
Margin	5%	\$125,000	\$41,625
Staging + relocations	2.50%	\$62,500	\$20,813
Investigation + design	8%	\$200,000	\$66,600
Insurance	1%	\$25,000	\$8,325
Statutory fees	1%	\$25,000	\$8,325
SYD project management	7%	\$175,000	\$58,275
Commissioning	5%	\$125,000	\$41,625
ICT	2.50%	\$62,500	\$20,813
Escalation	2.50%	\$62,500	\$20,813
Contingency	10%	\$250,000	\$83,250

Overhead Cost Component	Overhead	Project 1 – ICT Infrastructure Upgrade	Project 2 – Cooling Towers Upgrade
Total Project Cost (TPC)	65.5%	\$4,137,500	\$1,377,788

Table 4 Project Overheads

Table 5 presents the five-year staging for sample projects.

Project / Year	Total Project Cost	2025-26	2026-27	2027-28	2028-29	2029-30
Project 1 – ICT Infrastructure Upgrade	\$4,137,500	\$0 (0%)	\$34,445 (2.5%)	\$413,336 (30%)	\$895,562 (65%)	\$34,445 (2.5%)
Project 2 – Cooling Towers Upgrade	\$1,377,788	\$0 (0%)	\$103,438 (2.5%)	\$1,241,250 (30%)	\$2,689,375 (65%)	\$103,438 (2.5%)

Table 5 Project Budgets

The estimated cost for the ICT Infrastructure Upgrade (Project 1) is \$2,000,000–\$2,500,000, depending on the compatibility of the existing field devices. The Total Project Cost (TPC), including project overheads, is \$4,137,500.

The estimated cost for the Cooling Towers Upgrade (Project 2) is \$832,500, based on both units requiring replacement. The Total Project Cost (TPC), including project overheads, is \$1,377,788.

3 Findings

A 20-year Asset Maintenance and Life Cycle Cost Model was developed for the sample hospital. The cost modelling covers the following cost categories:

- Preventative Maintenance
- Corrective Maintenance
- Asset Replacement
- Asset Refurbishments
- Remediating Chronic Issues

The average yearly preventative maintenance cost component for the hospital, based on the bottom-up cost model outlined in Section 2.2, is \$1,145,554. This figure includes the preventative maintenance costs for all maintainable assets within the scope of the project.

The average estimated budget for the corrective maintenance cost component for the hospital, based on the bottom-up cost model, is \$766,684. The fluctuation in annual corrective maintenance costs over the 20-year period is due to this cost component is a function of both the condition assessment of the assets, carried out as part of the project, and the aging of assets over time. For example, the corrective maintenance cost decreases after an asset is replaced and increases as the asset continues to age throughout its life cycle.

The total estimated budget for the hospital’s asset replacement cost component, based on the bottom-up cost model outlined in Section 2.4, is \$58,815,373 over the next 20 years, while the asset refurbishment cost component over the same period is \$12,633,642.

Table 6 and Figure 4 present the 20-year lifecycle expenditure from the bottom-up cost model for the sample hospital.

3.1 Cost Modelling Limitations

It is important to note that the cost model may underestimate full amount required for maintenance and capital costs of the hospitals for the following reasons:

1. The modelling only covers maintainable building and facility assets recorded in the asset management information system. If assets are not recorded in the asset management information system, the modelling underestimates the required costs across all maintenance categories.
2. The modelling excludes fixtures, fittings, furniture, and equipment.
3. Fleet, food services, and laundry services assets were also excluded from the modelling.
4. Biomedical assets were not included in the modelling.

The cost models exclude the following cost components:

- Replacement of buildings at the end of their useful life.
- Grounds maintenance.
- Soft services.

Year	Preventative Maintenance	Corrective Maintenance	Asset Refurbishment	Asset Replacement	Remediating Work	Grand Total
2026	\$1,145,554	\$650,923	\$537,091	\$165,296	\$510,602	\$3,009,466
2027	\$1,145,554	\$691,808	\$746,302	\$459,280	\$5,044,230	\$8,087,173
2028	\$1,145,554	\$696,953	\$1,288,470	\$1,224,740	\$11,582,084	\$15,937,801
2029	\$1,145,554	\$738,199	\$993,100	\$525,641	\$4,972,457	\$8,374,952
2030	\$1,145,554	\$797,755	\$773,830	\$3,143,614	\$4,407,846	\$10,268,600
2031	\$1,145,554	\$824,867	\$345,418	\$153,829	\$1,566,190	\$4,035,858
2032	\$1,145,554	\$698,633	\$133,494	\$6,545,323	\$577,565	\$9,100,569
2033	\$1,145,554	\$751,990	\$533,039	\$79,202	\$20,560	\$2,530,345
2034	\$1,145,554	\$775,462	\$1,714,637	\$685,666		\$4,321,319
2035	\$1,145,554	\$735,199	\$544,538	\$1,981,708		\$4,407,000
2036	\$1,145,554	\$718,027	\$79,367	\$3,408,485		\$5,351,434
2037	\$1,145,554	\$770,229	\$712,775	\$536,265		\$3,164,823
2038	\$1,145,554	\$868,806	\$776,965	\$10,928,616		\$13,719,941
2039	\$1,145,554	\$857,078	\$1,048,712	\$492,771		\$3,544,116
2040	\$1,145,554	\$839,598	\$616,111	\$6,495,171		\$9,096,434
2041	\$1,145,554	\$904,213	\$379,976	\$122,759		\$2,552,502
2042	\$1,145,554	\$804,281	\$432,958	\$3,684,572		\$6,067,364
2043	\$1,145,554	\$695,565	\$51,644	\$5,324,340		\$7,217,104
2044	\$1,145,554	\$727,698	\$129,826	\$12,851,403		\$14,854,481
2045	\$1,145,554	\$786,403	\$795,389	\$6,691		\$2,734,037
Grand Total	\$22,911,080	\$15,333,688	\$12,633,642	\$58,815,373	\$28,681,533	\$138,375,317
Annual Avg.	\$1,145,554	\$766,684	\$631,682	\$2,940,769		\$6,918,766

Table 6 Cost Modelling Results for the Sample Hospital

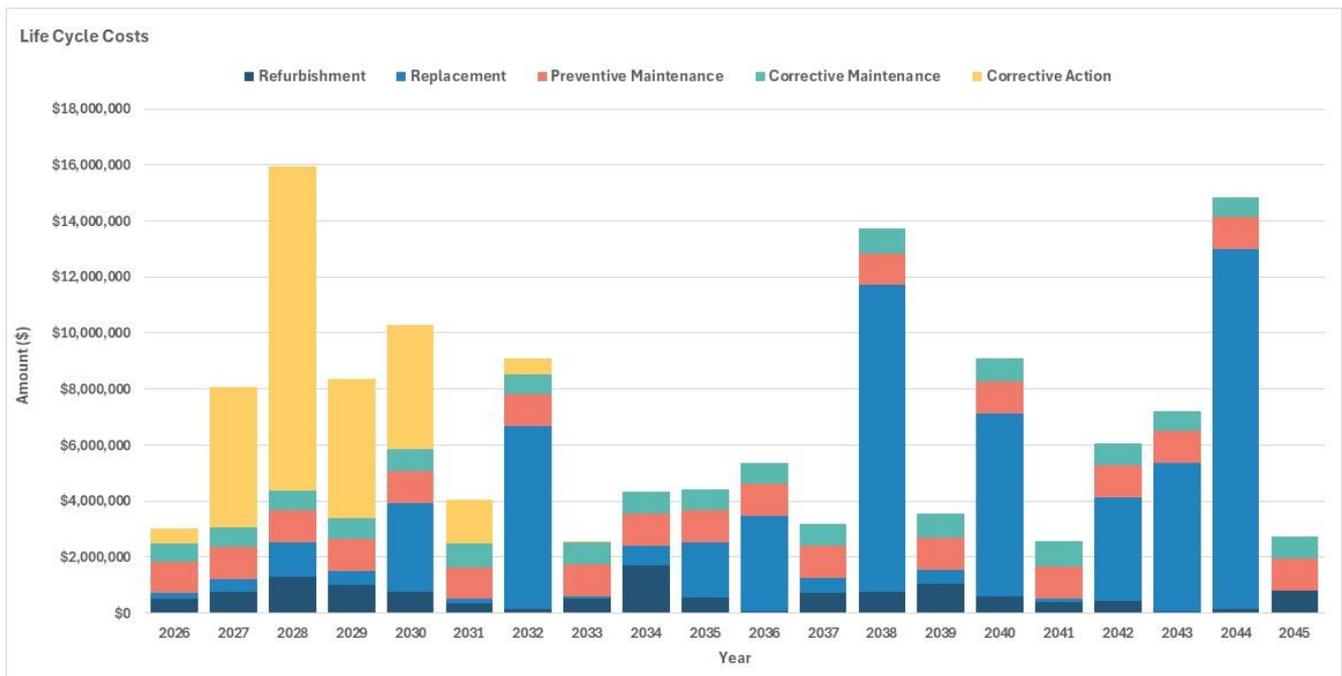


Figure 4 Cost Modelling Results for the Sample Hospital

4 Conclusions

This paper demonstrates that extending the operational life of healthcare facilities requires a structured, data-driven approach supported by validated asset information and evidence-based lifecycle modelling. The asset audit and subsequent development of an asset register enabled an accurate understanding of the hospital’s asset base and its condition. Applying a bottom-up lifecycle cost model provided clear forecasts of preventative and corrective maintenance requirements, asset refurbishment and replacement needs, and the funding necessary to address chronic issues affecting reliability, compliance, and operational performance of the facility.

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