# LIFE CYCLE ASSET MANAGEMENT

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## ABSTRACT

Many of the buildings, which will serve well in the 21st century, already exist. In many cases however inadequate funding has led to their premature deterioration. This is reflected in an increasing backlog of deferred maintenance tasks and an inability to meet ongoing component renewal requirements.

The stock of existing buildings can continue to provide an acceptable environment for the people and processes they house. However, without due attention, replacement facilities will be required and capital expenditure and resource use will increase unnecessarily.

In 1991, the deferred maintenance backlog of US colleges and universities was reported to be US $60 billion, which represented 20% of the replacement value.

This paper extends a tried and effective tool for building condition management. It uses a life cycle approach to ensuring HVAC systems (and other building elements) are maintained in a proactive manner.

The methodology proposed is a practical tool developed to identify, quantify and prioritize deferred maintenance and component renewal in a facility; to develop and report on the results of alternate levels of short and long term funding; and to develop a detailed deferred maintenance reduction plan based on the adopted funding level.

It defines and quantifies the current condition of a facility; a desired future condition; and how the desired future condition will be attained in terms of both maintenance tasks and costs. The task listings are of particular value for operations personnel, and the financial data for management.

The tool can be used for a single building or multiple buildings. Of particular value, is the ability to prioritize needs by building, building area, trade, building system or building element. In determining such priorities, building specific factors, such as revenue generation, can be included in the evaluation.

The method can be utilized for any building type and is equally applicable to old and new buildings. It can be applied in a manual format as well as a fully computerized version. The life cycle asset management model is an effective means of predicting, planning and monitoring building condition, including HVAC system maintenance.

## INTRODUCTION

Many of the buildings, which will serve us well into the 21st century, already exist. In many cases however, inadequate funding has led to their premature deterioration. This is reflected in an increasing backlog of deferred maintenance tasks and an inability to meet ongoing equipment, or component renewal requirements.

The stock of existing buildings can continue to provide an acceptable environment for the people and processes they house. However, without due attention, replacement facilities will be required, and capital expenditures and resource use will increase unnecessarily.

In 1991, it was estimated (NACUBO 1991) that the deferred maintenance backlog of US colleges and universities was US $60 billion, or 20% of the replacement value.

While the topic of this paper is the management of the physical condition of buildings, the secondary effects of deteriorating building systems cannot be overlooked. Poorly maintained mechanical systems will increasingly be incapable of maintaining an acceptable indoor environment. It has been shown (Dorgan, Linder and Dorgan 1998) that there is a statistically significant relationship between a building's indoor air quality and the level of maintenance performed on the building systems. Similarly, deteriorating building envelope components and aging light fixtures are typical of the deferred maintenance deficiencies which further contribute to reduced building performance.

Many organizations today have a very significant investment in existing building infrastructure. Clearly, the long-term management of these assets is key to the protection of the investment. What is required is a simple and effective tool for life cycle asset management (LCAM). A tool which will assess the current condition of a facility and provide a framework for achieving a desired future condition.

The LCAM system described in this paper was developed initially from the life cycle evaluation of 150 buildings for both the City of Calgary and the Federation of Calgary Communities, and was then refined using the NACUBO model. The system, as presented, was applied in full to the Family Leisure Centre in Calgary initially in 1993 and again in 1999.

## THE LCAM MODEL

Life cycle asset management comprises of four key elements; preventative maintenance, deferred maintenance reduction, component renewal and functional upgrading. While all four elements are important, the model presented in this paper deals predominately with deferred maintenance and component renewal.

Deferred maintenance deficiencies are defined as maintenance tasks which have been postponed as a result of a lack of funding, manpower, or priority. Component renewal is defined as the replacement of equipment or system elements which have reached, or are approaching, the end of their useful life.

Life cycle asset management is a practical tool devised to identify, quantify and priorize deferred maintenance in a facility and to develop a detailed deferred maintenance reduction plan based on an adopted funding level. It defines and quantifies the current condition of a facility; a desired future condition; and how the desired future condition will be attained in terms of both maintenance tasks and costs.

The process entails four key steps:

1. Facility inspections.

2. Estimating needs (costs) for;

   - deferred maintenance, and

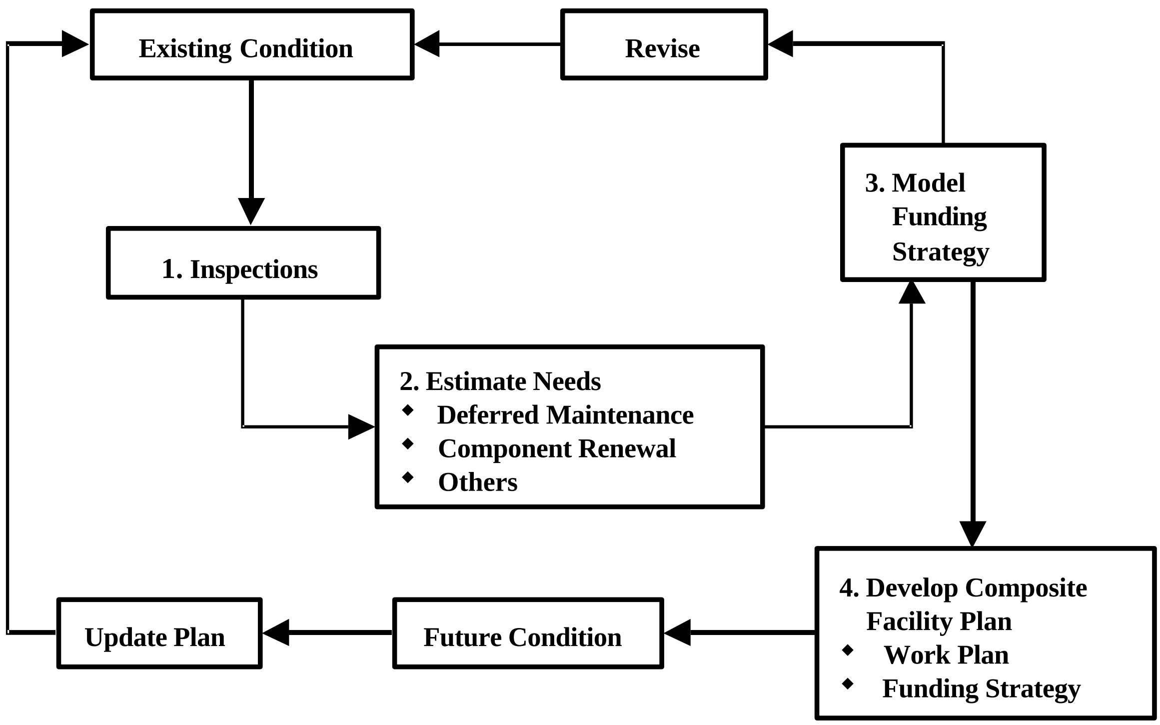
   - component renewal.

3. Model funding alternatives.

4. Develop facility plan.

Figure 1 illustrates how these four steps together form a model of the building life cycle asset management process.

**Figure 1: Life Cycle Asset Management Model**




**Facility Inspections**

The process begins with a multi-discipline team conducting a thorough inspection of the facility. If all systems in the building are being included in the facility plan, the team should include an architectural representative and structural, mechanical and electrical engineers. If the scope of the plan is being limited, then a representative of only those disciplines included is required. In all cases, the inspection team can be owner's personnel, external consultants, or any combination of the two. The scope of the plan can also be expanded to include room fixtures, fitting and equipment where knowledgeable personnel are available. Other specialists such as medical gas testing firms or roofing inspectors may also be added to the team as appropriate. In all cases, the inspectors must be experienced and knowledgeable practitioners within their field. In most cases, the inspection is entirely visual and therefore the inspectors are called upon to make value judgements by extrapolation from their observations.

For ease of inspection, each discipline (i.e. architectural, mechanical etc.) is divided into a number of individual components. The mechanical systems, for example, can be divided into eight basic components. These eight components are;

| | | | |
|---|---|---|---|
| M01 | Site Services | M05 | Cooling |
| M02 | Plumbing | M06 | Fire Protection |
| M03 | Heating | M07 | Medical Gases |
| M04 | Ventilation | M99 | Miscellaneous |

Each of these components can then be further divided into sub-components. Plumbing for example can have the following five sub-components;

| | | | |
|---|---|---|---|
| M02 | Plumbing | M0211 | Domestic Water |
| | | M0212 | Sanitary Drainage |
| | | M0213 | Storm Drainage |
| | | M0214 | Plumbing Fixtures |
| | | M0215 | Special Systems |

In this way, we can divide the four main building disciplines into some 34 components and over 100 sub-components. Being able to look at a building in such “bite sized” pieces enables the team to clearly focus their inspection efforts and aids in costing the repair work.

The inspection team is required to look at the building with two hats. They must consider the shorter timeframe deferred maintenance deficiencies in some detail, while taking a more global approach to future component renewal. Typically, deferred maintenance deficiency repair will be scheduled, year by year, over a five year period and capital renewals scheduled in 5-year bins over up to 20 years.

The data gathered with respect to the deferred maintenance deficiencies will include building component and sub-component; a sequential reference number and deficiency rating, location and description. A deficiency repair cost will be added later. The deficiency rating system is flexible and can be adjusted to meet specific project needs. One system uses the numbers 1 to 5 to designate within how many years the deficiency should be corrected. The number 0 is reserved for code violations, or other matters requiring immediate attention.

The future component renewal costs are generally identified by building component only. For each component, the future renewal costs are developed and placed in the appropriate 5-year bin.

**Estimate Needs (Costs)**

Having developed a database of deferred maintenance deficiencies and future component renewals, it is then necessary to estimate the cost, in current dollars, of repairing these deficiencies, or replacing the equipment or systems. Various costing sources are available including past projects, contractor quotes, cost data books and detailed take-offs. Future component renewal costs, particularly those further into the future, will be more allowances than specific costs. It is more important to identify the magnitude of such future costs than be bogged down by detailed estimates.

The current condition of the facility can now be quantified using the total estimated cost for all deferred maintenance deficiencies (DM$) and the current replacement value (CRV) of the facility. The facility condition index, or FCI, is defined as follows;

$$FCI = \frac{DM\$}{CRV}$$

NACUBO suggests that the FCI can be qualitatively interpreted as follows;

| | |
|---|---|
| Less than 0.05 | Good |
| 0.05 to 0.10 | Fair |
| more than 0.10 | Poor |

While the FCI is a simple tool, it is a most useful relative assessment, and is of value in prioritizing limited funds. The FCI can be calculated for areas within a building, buildings within a complex, or both. It can also be calculated for each building component.

**Model Funding Alternatives**

Having quantified the current condition of the facility, it is then possible to determine a desired future condition. Our goal, for example, might be to reduce the building FCI from 0.12 (poor) to 0.04 (good) in five years.

The cost of achieving this goal is not simply the current deficiency repair costs, which have already been identified. To provide realistic budgeting of the true cost, we must consider inflation, facility growth, plant deterioration and deficiency deterioration. It is assumed that existing deficiencies will deteriorate faster than components currently in good repair.

The formula used to consider these factors, and hence estimate the actual funding which will be required is;

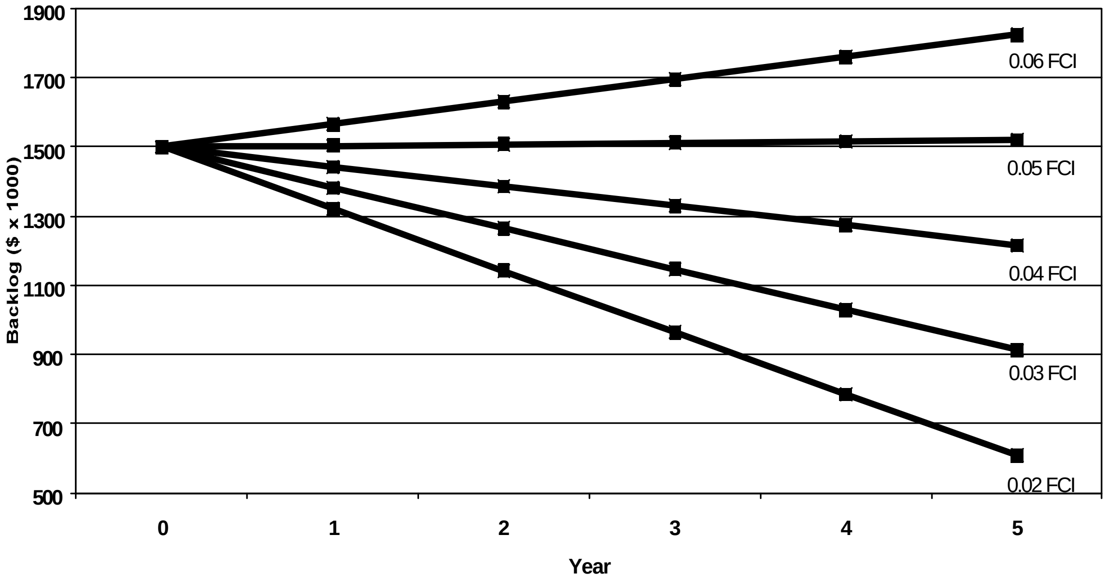
$$F_n=(B_{n-1})(1+ I_n+D_n) + (V_n)(P_n) - B_n$$

Where;

F = projected annual funding
B = value of deficiency backlog
I = inflation rate
D = deficiency deterioration rate
V = current replacement value, where at end of year n
$IV_n = (V_{n-1})(1+I_n+G_n)$
P = general plant deterioration rate
G = facility growth rate
n = year considered

Using this formula, various funding strategies can be tested. For each the value of the remaining deficiencies, and hence the resulting FCI, can be determined. In this way the future results of varying funding levels can be clearly communicated to management. A graphic similar to that shown in Figure 2 can be most useful in this regard.

**Figure 2: Funding Options vs FCI**




Care must be exercised in the use of the funding formula. The example building examined in Table 1 illustrates the sensitivity of the formula to a 0.5% increase in the inflation rate, deficiency deterioration rate, plant deterioration rate or facility growth rate. As Table 1 indicates, the formula is particularly sensitive to the plant deterioration rate. This sensitivity results from the fact that this variable is applied directly to the current replacement value, a far higher figure than the backlog value.

**Develop Facility Plan**

There are two components in the final facility plan; a work (task) plan and a funding plan. The work plan is of distinct value to operations and maintenance personnel in identifying the specific tasks, which must be undertaken to improve the condition of the facility. The funding portion of the plan is of value to management in planning for and justifying future funding requirements.

The work plan derives directly from the deferred maintenance deficiency database developed at the inspection stage. The data can be sorted by any of the recorded parameters including building, system, priority etc. The previously assigned sequential deficiency numbers are also useful in cross-referencing specific deficiencies. By grouping deficiencies by priority and building sub-component for example, a number of individual plumbing tasks can be packaged into a manageable piece of work for internal staff or an external contractor.

The funding plan will normally incorporate deferred maintenance and component renewal costs. Preventative maintenance costs and any known future functional upgrading costs can also be included if appropriate.

**Table 1: Funding Formula Sensitivity**

| | YEAR | | | | |
|---|---|---|---|---|---|
| **Variation** | **1** | **2** | **3** | **4** | **5** |
| Base calculation* | 521,669 | 534,436 | 547,826 | 561,866 | 576,580 |
| Base calculation with interest rate ($I_n$) = 2.5% | 525,139 | 539,981 | 555,617 | 572,082 | 589,414 |
| Base calculation with backlog deterioration rate ($D_n$) = 3.5% | 529,169 | 541,653 | 554,760 | 568,516 | 582,947 |
| Base calculation with plant deterioration rate ($P_n$) = 2.0% | 651,669 | 669,636 | 688,434 | 708,098 | 728,662 |
| Base calculation with plant growth rate ($G_n$) = 2.5% | 517,639 | 532,735 | 548,625 | 565,344 | 582,929 |

* Base Calculation $I_n$ = 2.0%, $D_n$ = 3.0%, $P_n$ = 1.5%, $G_n$ = 2.0% with CRV = $25 million, $B_o$ = $1.5 million, $FCI_5$ = 0.04

**A CASE STUDY**

The Family Leisure Centre is a 10,000 $m^2$ multi-function recreation facility located in south Calgary. The building, which is owned and operated by the four neighboring communities, comprises of a hockey arena, a curling arena, a wave pool, a restaurant, a racquet courts area, a weight room, classrooms, meeting rooms and lounge area.

The building was constructed in 1982, and at the time of the initial LCAM evaluation in 1993, had not undergone any significant refurbishment. The 1993 replacement value of the facility was estimated to be $12,500,000.00 Canadian.

The 1993 evaluation of the building revealed a deferred maintenance backlog of $770,950.00 or a facility condition index (FCI) of 0.062 – a rating that was interpreted as fair.

The 1993 deferred maintenance reduction plan developed for the facility was based on the five year goal of reducing the building FCI to 0.05, the threshold of a good rating.

In 1999, a second life cycle asset management evaluation of the facility was undertaken.

By each of the major building areas, the 1993 and 1999 deferred maintenance deficiency costs were as indicated in Table 2. The deficiency costs can also be evaluated by discipline as indicated in Table 3.

**Table 2: Deferred Maintenance Backlog by Area ($ Canadian)**

| Area | 1993 | | 1999 | |
|---|---|---|---|---|
| | **$** | **%** | **$** | **%** |
| Aquatics | 275,750 | 35.8 | 301,700 | 40.9 |
| Ice Facilities | 168,400 | 21.8 | 147,325 | 20.0 |
| Administration | 70,000 | 9.1 | 80,300 | 10.9 |
| Program Wing | 29,200 | 3.8 | 30,500 | 4.1 |
| Dry Sports | 77,100 | 10.0 | 77,700 | 10.5 |
| Restaurant | 22,500 | 2.9 | 13,000 | 1.8 |
| Service Areas | 107,200 | 13.9 | 51,700 | 7.0 |
| Outside | 20,800 | 2.7 | 35,800 | 4.8 |
| **Total** | **770,950** | **100** | **738,025** | **100** |
| Current Replacement Value | 12,500,000 | - | 14,500,000 | - |
| FCI | 0.062 | | 0.051 | |

**Table 3: Deferred Maintenance Backlog by Discipline ($ Canadian)**

| Discipline | 1993 | | 1999 | |
|---|---|---|---|---|
| | **$** | **%** | **$** | **%** |
| Architectural | 311,400 | 40.4 | 326,500 | 44.2 |
| Structural | 248,200 | 32.2 | 272,700 | 37.0 |
| Mechanical | 164,800 | 21.4 | 98,900 | 13.4 |
| Electrical | 46,550 | 6.0 | 39,925 | 5.4 |
| **Total** | **770,950** | **100** | **738,025** | **100** |

FCI values were also calculated for individual areas within the facility. The purpose of this refinement was to ensure that funding priority would be given to those areas which contributed most to revenue generation. Table 4 illustrates the effect of the weightings applied using these criteria. This same methodology could be applied to other facility types with the weighting factor being based on a project specific key parameter.

**Table 4: 1993 Area FCIs Adjusted for Revenue Generation**

| Area | FCI | Weighting (W) | FCI x W |
|---|---|---|---|
| Aquatics | 0.079 | 32 | 2.528 |
| Ice Facilities | 0.061 | 32 | 1.952 |
| Program Wing | 0.058 | 11 | 0.638 |
| Restaurant | 0.036 | 14 | 0.504 |
| Dry Sports | 0.043 | 11 | 0.473 |
| - | - | 100 | - |

The component renewal costs were evaluated for the two 5-year bins, years 6 – 10 and years 11 – 15. The results of this evaluation are indicated in Table 5.

**Table 5: Component Renewal Cost Projections ($ Canadian)**

| Area | 5 Year Bin | | | |
|---|---|---|---|---|
| | 1993 Evaluation | | 1999 Evaluation | |
| | 2000 – 2004 | 2005 – 2009 | 2005 – 2009 | 2010 - 2014 |
| Aquatics | 107,000 | 226,000 | 196,000 | 41,000 |
| Ice Facility | 43,000 | 228,000 | 110,000 | 143,000 |
| Administration | 100,000 | 190,500 | 125,400 | 72,000 |
| Program Wing | 34,200 | 62,200 | 31,700 | 25,000 |
| Dry Sports | 77,000 | 136,000 | 105,000 | 45,500 |
| Restaurant | 7,500 | 57,000 | 1,500 | 11,000 |
| Service Components | 10,500 | 75,500 | 27,000 | 313,000 |
| Outside | 1,000 | 16,000 | 47,000 | 22,500 |
| **Total** | **380,200** | **991,200** | **643,600** | **673,000** |

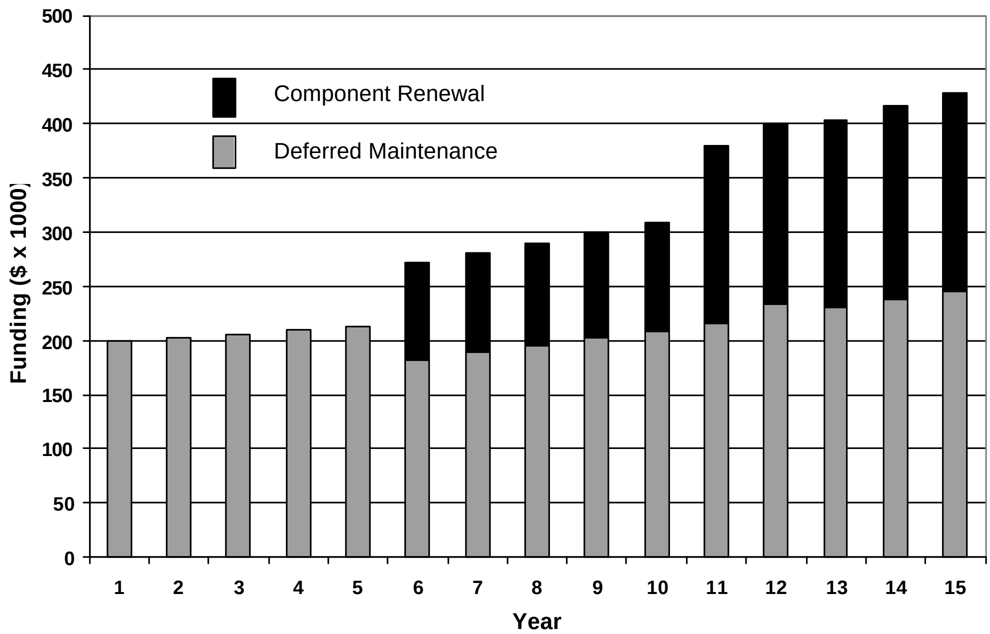
The 1993 deferred maintenance reduction plan was based on achieving a FCI of 0.05 at the end of the five-year period. The current replacement value, backlog, required funding and resulting FCI to achieve this goal were calculated using the funding formula and are indicted in Table 6.

**Table 6: 1993 Backlog Reduction Plant ($ Canadian)**

| Year | Current Replacement Value | Backlog | Funding | FCI |
|---|---|---|---|---|
| 1993 | 12,500,000 | 770,950 | - | 0.062 |
| 1994 | 12,875,000 | 761,660 | 199,720 | 0.059 |
| 1995 | 13,261,000 | 752,370 | 202,830 | 0.057 |
| 1996 | 13,660,000 | 743,080 | 206,080 | 0.054 |
| 1997 | 14,069,000 | 733,790 | 209,430 | 0.052 |
| 1998 | 14,490,000 | 724,500 | 212,890 | 0.050 |

The composite funding required includes both backlog reduction and future component renewal funding. If the five-year bin amounts for component renewal are equally distributed, on an annual basis, then a composite-funding graphic as illustrated in Figure 3 can be produced.

**Figure 3: Composite Funding Requirements**



The deferred maintenance reduction work plan developed in 1993 grouped identified deficiencies by year (0 to 5) and by trade to provide year by year work packages. An example for year one is shown in Table 7.

**Table 7: 1993 Work Plan – Year 1 ($ Canadian)**

| No. | Description | Deficiencies | Cost |
|---|---|---|---|
| 1 | Repair outsulation | 001. | 25,000 |
| 2 | Miscellaneous interior painting and re-finishing | 003,004,005,007, 016,046,065,066. | 38,500 |
| 3 | Re-roof aquatics | 025. | 100,000 |
| 4 | Controls verification and repair | 080,102,114,199. | 11,500 |
| 5 | Fire protection work | 033,116. | 6,000 |
| 6 | Architectural repair and replacement | 002,012,013,017, 019,022,049,099. | 25,200 |
| 7 | Mechanical repair and replacement | 028,024,058,135, 176,189,196,202. | 11,000 |
| 8 | Electrical repair and replacement | 041,063,161,209. | 5,000 |
| 9 | Outside work | 213,215,216,217. | 6,300 |
| 10 | Main backflow preventer | 187. | 17,500 |
| | TOTAL | | 246,000 |

In 1999, the second life cycle evaluation of the Family Leisure Centre indicated a current deferred maintenance backlog of $738,025 Canadian, within 2% of that project for 1998 in the 1993 evaluation. Assuming a current replacement value of $14.5 million Canadian, the 1999 FCI is 0.051, which compares favorably with the 1993 target.

The 1999 backlog reduction plan is currently being developed. It is likely that a target FCI of 0.042 will be set.

## CONCLUSION

The Life Cycle Asset Management model outlined is a simple but effective tool for managing the future condition of a facility. It can be applied to new or older facilities, and can usefully be applied to multi-building complexes or campuses. The concept of the facility condition index allows buildings, areas within buildings, components or sub-components to be prioritized. This is of particular value in making decisions as to where limited funds should be spent.

Clearly, being essentially a database, the model readily lends itself to computerization. Such a version is currently being tested on two buildings for Alberta Infrastructure, the Provincial Public Works Department.

Through the use of the LCAM model, facility managers have a means of proactively managing the condition of their facilities. By extending the useful life of existing buildings, we will delay the need for new facilities, thereby reducing capital expenditures and minimizing resource use. We will also contribute to maintaining acceptable environmental conditions and overall performance in these buildings.

## ACKNOWLEDGEMENTS

The assistance provided by Family Leisure Centre staff during both the 1993 and 1999 evaluations is greatly appreciated.

## REFERENCES

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