Municipal Portfolio Stewardship with Limited Budgets: The Application of Matrix Correlations as a Tool to Support Resource Allocation Decisions in the Public Good

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Abstract

Portfolio managers are often challenged with difficult decisions in balancing the distribution of limited resources, particularly across groups of buildings of varying attributes, such as age, size, function, and states of physical condition and functional obsolescence. These complex decisions require insight into the correlations (or relationships) between a multitude of physical and financial attributes. Budget constraints compel the managers to prioritize the resource allocations, which requires the development of a compelling business case to support the skewed distribution of the funds to certain facilities and critical assets during particular fiscal years. This paper presents a methodology that draws upon a matrix correlation tool that has been used to help municipalities establish a defensible resource distribution amongst civic departments, motivated by the public good rather than profit incentive. While the weightings for the variables will differ based upon the owners' objectives (either in the public sector or private sector), the principles of matrix correlations apply to all real estate sectors, including municipal, commercial, industrial and institutional.

1 Introduction

Municipalities in British Columbia (BC), Canada provide public services across an area of 944,765 square kilometres [5] to numerous urban and rural communities, ranging in size from less than 5,000 residents to over 600,000 residents in the bigger cities, such as Vancouver [5]. To service their communities effectively, each municipality contains anywhere from five buildings to 300 civic buildings in their portfolio, including fire halls, police stations, works yards, swimming pools, ice arenas, libraries, museums, seniors centres, childcare centres, storage buildings, parks washrooms, stadiums and animal welfare shelters. These facilities are varied in terms of their age, size, physical condition, functional obsolescence, energy efficiency, mission criticality and geographical location.

Since the early 2000s, the authors have been involved in the preparation of capital plans, facility condition assessments, energy audits and maintenance plans for a cross-section of portfolios in the commercial, institutional and municipal sectors. The findings and recommendations of these studies have been presented to Boards of Directors, Committees, City councils, executive groups and the facility management departments.

2 The Decisions

Through interactions with elected local government officials and city staff, the authors have participated in dialogues on the challenges in making reasoned and defensible decisions in the public interest. While the challenges for municipal managers are many and varied, the focus of this paper is on the data correlations deemed necessary to assist in contemplation on the following four types of decisions, all of which are different manifestation of the challenge of the appropriate allocation of resources.

2.1 Re-investment or Re-development of a New Facility

One of the key decisions arising in older facilities, particularly those that are suffering from an extensive backlog of deferred maintenance and/or becoming functionally obsolete, is whether to continue to reinvest in the sustainment of the aging facility by renewing major components, such as roofs and boilers, or to completely reconstruct that facility. This is referred to as the "Reinvestment-Redevelopment" problem.

2.2 Adaptive Renewal or Like-for-Like Renewal

Adaptive renewal opportunities - arising from new products and technologies - pose a challenge for the decision makers. One of the most common examples is energy efficiency measures, such as the replacement of a mid-efficiency boiler with a new high-efficiency condensing boiler. The decision makers are tasked with having to evaluate the costs and benefits of either leveraging the existing boiler while it continues to fulfil its remaining service life (which could be many years or decades) or invest in the upgrade now with upfront incremental cost but also paybacks through reduced energy consumption. This is referred to as the "Defender-Challenger" problem.

2.3 Run-to-Failure or Just-in-Time Replacement

Run to failure (RTF) is a conscious decision to neglect an asset, or facility, with full knowledge of the consequences of such inaction. Sweat-the-asset (STA) is a colloquial expression for extracting life from an asset beyond its intended design life. While these approaches are not permitted with statutorily regulated assets, such as fire safety equipment, there are some assets that are acceptable candidates for RTF or STA -- but only under controlled conditions and with sophisticated knowledge of the leading indicators of asset deterioration and failure. These strategies typically result in the skewed reapportionment of limited capital towards the deemed mission-critical facilities and controlled "drift" of the backlog of deferred maintenance at the non-critical facilities until a point of diminishing returns that is concomitant with the owners' risk threshold. The navigation of the time periods leading up to these failure points is referred to as the "Risk Threshold" problem.

2.4 Freehold or Leasehold Acquisitions

A fourth decision facing the portfolio management team is whether to satisfy an emerging need by constructing a new facility (freehold) or entering into a lease agreement (leasehold) on an existing property. Each portfolio owner will find an optimal freehold:leasehold ratio that complements the balance of assets and interests under their stewardship. This problem is referred to as the "Assets vs. Interests" problem.

These four classes of decisions arise in different ways over the life a facility and will vary in their prevalence and impact across different types of portfolios in the public and private sectors. Resource allocation decisions can also be applied to choices at the facility-level (eg. money to buildings #6, #9 or #44) or at the component-level (eg. money towards the roof or boiler at Building #6). These decisions are multi-faceted and require insight into the correlations between many physical attributes (such as facility age) and financial attributes (such as energy intensity) in order to understand the cascading impact of decisions.

3 The Methodology

In working with different portfolio managers, over the course of a decade, the authors developed a nine step methodology resulting in a multivariate decision-support tool to establish the business case to support skewed resource allocations and to test the efficacy thereof.

3.1 Identify the Facility Attributes (Variables)

The first step in the methodology is to identify the different attributes (or characteristics) of facilities that are pertinent, in varying degrees, to making resource allocation decisions. While the most obvious attributes are "facility age (years)" and "facility condition ($)", the authors have identified 18 potential attributes that include more sophisticated concepts, such as energy-use-intensity and post-disaster designation. Regardless of the varying forms of attributes - physical vs. financial; quantitative vs. qualitative - all are isolated and translated into numerical variables that can be compared. Some of the variables take the form of integers (such as "20 years old") or indexes (such as a "3.3% energy intensity") or monetary values (such as "$2.3 Million capital load"). While some of the attributes are beyond the control of the facility operators (such as facility age) there are many attributes over which they do have some influence (such as energy efficiency) and significant opportunities can be leveraged in resource planning and resource allocation decisions.

3.2 Attach a Scoring System to Each Attribute

Once the facility attributes have been translated into numerical variables, a scoring system is established and normalized so that it recognizes the ranges, minimums and maximums in each attribute. The scoring scale is consistent to a scale of 1-10 for all attributes where the distribution of scores reflects the different degrees of manifestation of the attribute. For example, the scoring for facility age as an attribute must recognize that younger facilities generally have different capital needs than older facilities and these needs change at different life stages. The resultant sliding scales are represented in the form of score distribution curves matched to each attribute. In reference to resource allocations, a younger building (say, a fire hall) may receive a lower score than an older building (say, an animal shelter). However, that same young building may receive a higher score on a different attribute, due to its higher mission criticality than the older building.

3.3 Attach Weightings to the Attributes

Recognizing that each of the facility attributes is important but they do not all have equal significance, particularly in reference to resource allocation decisions, a weighting is attached to each attribute. The weightings are a multiplication factor applied to the score of a particular attribute so that its relative importance can be factored into the aggregated score. The attributes that are more pertinent to resource allocation decisions (such as deferred maintenance levels and future renewal forecasts) will receive a higher weighting. The weightings also provide for a sensitivity that can be adjusted to match needs across different types of portfolios that may be organized into different real estate classes (such as industrial, civic, or institutional), organized into civic department (such as fire, parks or cultural), by portfolio sector (public, private) or geographical location (such as climate zone or seismic zone). A municipal portfolio (focused on the public interest) will weight the attributes differently to a commercial portfolio (motivated principally by profit).

3.4 Compare the Attributes on a Scatter Plot

A correlation is the relationship between two or more sets of data (such as facility age and level of deferred maintenance), which can be represented as a scatter plot. These two dimensional displays, typically overlaid onto a matrix, can be useful for visualizing relationships and extracting insight to evaluate against key performance indicators (KPIs). For example, the correlation between the age of a facility ('x' axis) and its condition ('y' axis) can be plotted on a matrix and compared with other facilities, where each facility is an observation point on the scatter plot. The correlation of two attributes (say age-condition) returns a bi-variate analysis, whereas the correlation of three or more attributes (say, age-condition-criticality) returns multivariate insight. Since some correlations are weak and others are strong, these trends can be used to point the decision makers towards appropriate weightings.

3.5 Identify Patterns across the Portfolio

Groups of facilities that share similar attributes (such as age or function) can be observed to determine if there are any consistent patterns in their behaviour and their ongoing performance expectations. For example, a matrix that is comprised of four quadrants would reveal facilities that share certain correlations. In the case of a municipal portfolio, it is important that the correlations be understood relative to the needs and available funding for each civic department: fire, parks & recreation, cultural, police services, etc.).

3.6 Recognize Operating Standards and Risk Tolerance

Before the facilities can be individually ranked, it is necessary to first apply the owners' target operating standards to the scoring system. In the absence of an operating standard, the matrix tool applies default values based on general industry standards. The goal is to ensure that certain attributes that can be manipulated by resource allocations (such as backlog of deferred maintenance) and measured against appropriate thresholds. Thresholds often correspond with key performance indicators employed by the different municipal departments and failure to set such thresholds, at reasonable levels, will serve to compromise the ranking system.

3.7 Rank Order the Facilities

Once the scores have been aggregated across all the pertinent attributes and weighted appropriately, the facilities are ranked with their relative scores, typically from highest score to lowest score. The size of the score increments between each facility will vary depending on the range of needs, where the highest scoring facilities are deemed to satisfy two criteria: a) in greatest need of capital infusion; and, b) best return on investment and/or alignment with the portfolio mission based on the various attributes.

3.8 Distribute Resources Based on the Rankings

The rankings, ordered from highest to lowest, provide the business case for allocation of resources to facilities deemed to be in greatest need and also with the best return on investment to the portfolio at a whole. In some cases there may be significant difference between the lowest and highest ranked facilities, where the latter receive the vast majority of the resource allocations, which resulted in a heavily skewed distribution. In other cases, the scores may only vary slightly between some or all facilities and capital is distributed more evenly across the portfolio.

3.9 Compare the Pre- and Post-Distribution Rankings

The final step in the process is to compare the results of the resource allocations in terms of the impact it has on the scores for each facility. For example, the allocation of $500,000 towards Facility #34 may lower its backlog of deferred maintenance, thereby reducing its funding needs and lowering its ranking. In some cases, the allocations may only represent a partial fulfilment of the capital needs and the facility may continue to rank relatively high, which will ensure that it remains on the priority list for consideration when the next round of funds are released.

3.10 Submit for Decision

Before making the final commitment to distribute the available capital funds, the portfolio management team may adjust some of the weightings and standards thresholds to test the sensitivity thereof.

4 The Attributes, Scores & Weightings

In consultation with the management teams of varied portfolios, in both the public and private sectors, the authors identified 18 attributes (or characteristics) of facilities that could be considered pertinent when making different types of resource allocation decisions. These are listed in the following master attribute table.

1*	Age of the Facility	**10***	Function
2*	Size of the Facility	**11**	Primary, secondary and tertiary uses
3*	Reproduction Value (CRN)	**12**	Number of systems and assets in the facility
4*	Mission Dependency Index (MDI)	**13***	Date of last condition assessment (FCA)
5*	Backlog of Deferred Maintenance (FCI)	**14***	Post-disaster designation (PD)
6*	Capital Load over Tactical Horizon (5 years)	**15**	Revenue generating capacity and lease income
7*	Capital Load over Strategic Horizon (30 years)	**16***	Energy use intensity (EUI) and efficiency (BEPI)
8	Adequate Replacement Reserves	**17**	Geographical location and bundled co-locations
9	Ownership Structure (Freehold or Leasehold)	**18**	Functional obsolescence (FNI)

The majority of these variables apply to all real estate sectors (civic, industrial, institutional, etc.) but a few of the variables are unique to public sector facilities (such as post-disaster designation). Furthermore, some of the attributes are quantitative (such as facility size and age), whereas others are more qualitative (such as facility backlog and mission dependency).

Drawing upon a database of 1,651 buildings [1,2] compiled over a 15 year period, the authors identified ten of the variables as being most pertinent to resource allocation decisions in a municipal portfolio setting. In comparison, revenue generation or lease income is an attribute more applicable to a commercial or industrial property portfolio.

4.1 Age of the Facility

The age of a facility may either be taken as the original date of construction of the oldest part of the facility or a careful blending of the ages of all the wings that have been constructed as additions over time. Recognizing that the level of reinvestment in facilities changes over time to match the lifecycles of significant components, such as roofs and boilers, and various studies have been conducted to ascertain funding requirements at different life stages [1,2,9,11], the following figure provides the scoring distribution curve developed to plot the age attribute.

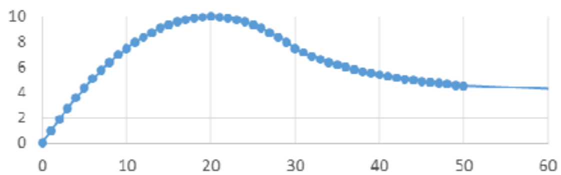

Figure 1: Scoring curve for facility age

Facilities that are 15-25 years old receive the highest score as they occupy the highest point on the age curve. Since age is consistently one of the more critical variables, in all types of portfolios, the weighting should be adjusted accordingly.

4.2 Size of the Facility

Generally, the greater the size of the facility the greater its significance to the municipality, particularly community nodes and revenue generating facilities such as aquatic centres and ice arenas. Since the largest municipal facilities are generally in the order of 100,000 square feet, Figure 2 provides the scoring distribution and sets the maximum achievable score at any facility over 60,000 square feet.

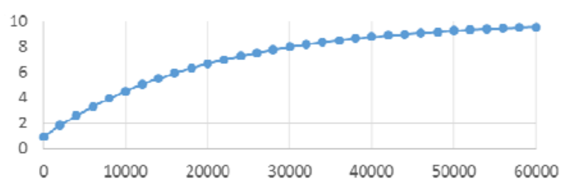

Figure 2: Scoring curve for facility size

There are some important exceptions to the rule that larger facilities are more important to the municipality. For example, fire halls are mission critical but typically in the order of 15,000 square feet. Therefore, a fire hall will score low on the size attribute but high on the mission criticality attribute.

4.3 Reproduction Cost of the Facility

The cost to reproduce the facility is derived from the insurance appraised value, which is updated annually. It is important that this value is isolated from the size of the facility by dividing the value into the gross floor area of the facility in order to arrive at a square foot (square metre) unit rate. The following graph reveals that the point scoring system increases until about $300 per square foot.

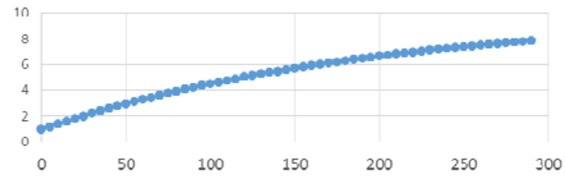

Figure 3: Scoring curve for facility reproducton value

The reproduction cost is a critical piece of data that is used as the denominator in the FCI, EFCI and FNI formulas [1, 2].

4.4 Mission Dependency Index

The Mission Dependency Index (MDI) is an operational risk metric for establishing the criticality of facilities based upon their relative importance to the owners' mission. The index provides a series of qualifiers to indicate the impact, or consequences, if a facility is deemed non-functional for reasons of physical deterioration or obsolescence [4]. For example, facilities will be deemed to fall into one of three criticality rankings: Mission Critical Facilities (such as fire halls and police services); Mission Dependent Facilities (such as recreation centres, libraries, museums); and Mission Independent Facilities (such as storage sheds). The following figure provides the graph to illustrate that the scoring increases directly with greater mission criticality.

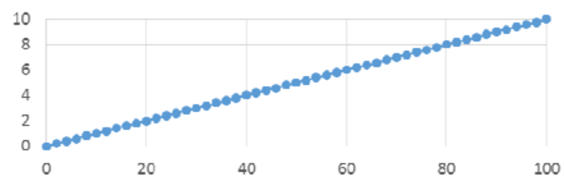

Figure 4: Scoring curve for the mission-dependency ranking

The MDI is closely connected to the primary use and function of the facility. In the case of a civic portfolio, fire halls and police services buildings are "mission critical", whereas pools and arenas are deemed "mission-dependent". A 3rd tier of mission criticality is labelled as "mission-independent" and is attached to facilities such as animal welfare shelters.

4.5 Backlog of Deferred Maintenance

The deferred maintenance at the facility at the time of the assessment is a measure of the “catch-up” costs to restore the facility to deemed acceptable condition [4]. The deferred maintenance quantum requires isolation from facility size so it is divided by the facility reproduction cost, which returns a Facility Condition Index (FCI). In accordance with industry standards, an FCI of 0-5% of facility reproduction value is deemed to be in relatively “good” condition, 5-10% relatively “fair” condition, 10-40% relatively “poor” condition and 40%+ is deemed “critical”. The following figure provide a graphical representation with the FCI percentages across the horizontal (x) axis.

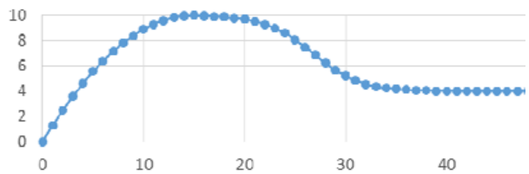

Figure 5: Scoring curve for deferred maintenance levels

At some point the FCI is so high that it makes no economic sense to continue to invest in the facility and it may be fiscally responsible to construct a new facility. While there is no industry consensus, which will likely vary between sectors, it is generally considered that an FCI of 50%+ indicates critical condition and the facility should be reconstructed rather than continued reinvestment in ongoing sustainment.

4.6 Capital Loads over Tactical and Strategic Horizons

The capital load is the combined value of the all capital projects that are forecast to occur over the planning horizon [4]. The planning horizon is typically set at one of the following forecast periods: 30-years (strategic); 10 years (tactical); 5-years (sub-tactical); and 1 year (operational). In light of the age profiles of municipal buildings, the authors selected the 5-year and 30-year capital loads.

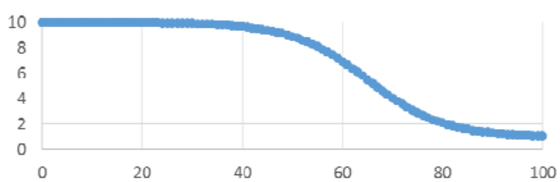

Figure 6: Scoring curve for capital load

The 5-year capital load indicates whether there are any significant asset renewal projects in the tactical planning horizon. This information is of paramount importance to all the different types of resource allocation decisions.

4.7 Date of Last Facility Condition Assessment (FCA)

A facility that has been subject to a facility condition assessment (FCA) provides the management team with useful empirical data to make informed decisions. However, these reports can quickly become stale, which is reflected in the following score curve.

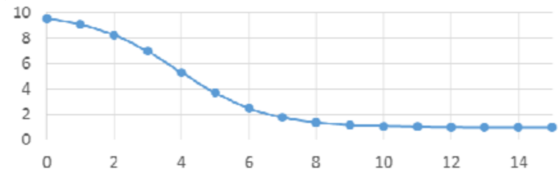

Figure 7: Scoring curve for condition assessment

The level of assessment and the quality of the assessment data is another consideration that impacts the scoring system, which are outside the scope of this paper.

4.8 Energy Use Intensity

The Energy Use Intensity (EUI), reported as KWh/Sq.M, reveals the amount of power and fuels used to operate the facility. The EUI is coupled with the Building Energy Performance Index (BEPI) to identify opportunities for adaptations or upgrades to the facility, carried out in the form of Energy Efficiency Measures (EEMs). These capital costs, including the incremental costs of the upgrades, are divided into the size of the facility in order to isolate and return a rate per square metre.

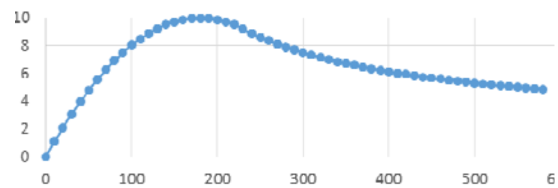

Figure 8: Scoring curve for EUI and BEPI

While an aquatic centre and ice arena are more energy intensive than a police station, they may simultaneously be more energy efficient than the latter. Depending on the availability of data, EUI and BEPI should be factored together as part of the same attribute.

4.9 Post-Disaster Designation

A post-disaster (PD) designation indicates that a facility has an intended secondary use that may exceed the mission criticality of the primary use. This attribute is considered unique to municipal portfolios. For example, an ice arena may be considered a tier-2 facility on the MDI scale but its secondary designation as post disaster (for food storage and/or morgue) will change the weighting score to tier-1 criticality. Since this attribute is evaluated as a true-false statement, there is no scoring curve.

The scoring on each of these facility attributes, or combinations thereof (such as FCA+EUI+PD), results in an aggregated score for each facility which can be ranked and compared against other facilities in the portfolio and compared over time, particularly after funding has been allocated to address deficient conditions (catch-up costs) or ongoing capital needs (keep-up costs).

It is paramount that the portfolio manager recognize which of the attributes are simple integer values (such as age) and which are generated from key performance indicators (such as the facility condition index). It is here that the correlations gain their most significance and provide deeper insight for decision making.

5 The Correlations

The data analytics generated from different types of correlations have been useful in helping portfolio decision makers, particularly in establishing a prioritization scheme and tabling a compelling business case for rational resource distribution amongst individual facilities.

The simplest means of presenting the correlations is in the form of a two dimensional matrix, where the purpose is:

- To draw correlations between data sets;
- To identify patterns in the data (such as trends and strong or weak correlations);
- To classify/organize data into groups for analytical and classification purposes;
- To benchmark individual assets or facilities against Key Performance Indicators (KPIs) and other measures or thresholds;
- To establish prioritization schemes.

Using a simple example to illustrate: "Do we replace our low-efficiency boiler with a high-efficiency boiler (with incremental capital cost and paybacks) or sustain the asset for the remainder of its 10 year service life". This decision requires a multivariate analysis of several pieces of data: age, condition, energy efficiency, capex for a similar boiler or energy enhanced boiler, and mission-criticality of the facility.

5.1 The Condition-Age Matrix

This matrix provides insight into the correlation between the condition of a facility and its age. The condition is measured by the Facility Condition Index (FCI).

It is sometimes assumed that there is a direct correlation between these two attributes, where older buildings are expected to be in poorer condition than younger ones. In reality, an older facility may be in excellent condition as a result of ongoing reinvestment by the owners and a young facility may be suffering from neglect or premature failure of some significant components.

In the condition-age matrix, each facility will be deemed to fall into one of the following four quadrants.

❶	Old buildings in good condition	✓
❷	Old buildings in poor condition	?
❸	Young buildings in good condition	✓
❹	Young buildings in poor condition	✗

Quadrants ❶ and ❸ represent desirable states; Quadrant ❹ is an undesirable state; and Quadrant ❷ presents a strategic choice that is context sensitive depending on the type and function of the facility.

Figure 9 provides a graphical summary of a municipal portfolio where the horizontal ('x') axis indicates the relative conditions of the facilities and the vertical ('y') axis represents the increasing age of the facilities. Colour coding is used to reveal the facilities in each municipal department.

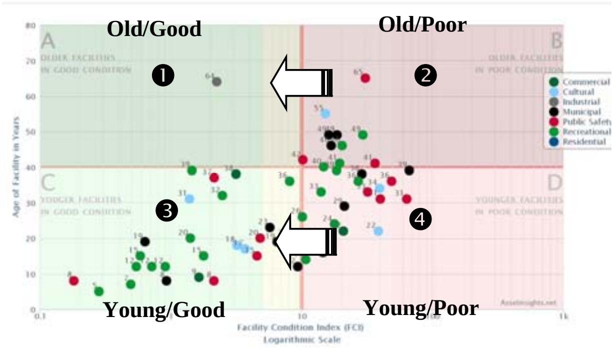

Figure 9: The condition-age matrix

The goal of the facility management group is to move facilities from Quadrant ❷ into Quadrant ❶ and from Quadrant ❹ to Quadrant ❸. To this end, the primary focus for management of the buildings intra-quadrant and inter-quadrant can be summarized as follows:

❶	Ongoing routine maintenance to sustain good performance, with adequate allowance for replacement reserves.
❷	Decision choice: a) significant repairs, renewals and restoration; or, b) controlled run to failure until redevelopment.
❸	Ongoing routine maintenance, with moderate allowance for replacement reserves.
❹	Implementation of significant repairs and renewals in order to restore baseline condition.

One of the key limitations of this matrix is the need for additional insight into the significance of functional obsolescence of facilities in Quadrant ❹ in order to inform a decision on reinvestment or redevelopment. It is not always prudent to continue to invest in older facilities that are becoming functionally obsolete.

5.2 The Condition-Energy Matrix

This matrix plots the relationship between the physical condition of a facility and its energy efficiency. The energy efficiency is measured by the Energy Use Intensity (EUI) and Building Energy Performance Index (BEPI). Facilities will land in one of four quadrants, as follows:

❶	Energy efficient buildings in good condition	✓
❷	Energy efficient buildings in poor condition	?
❸	Energy inefficient buildings in good condition	?
❹	Energy inefficient buildings in poor condition	✗

Buildings in Quadrant ❶ represent the most desirable state; Quadrants ❷ presents a strategic choice; Quadrant ❸ indicates a realignment opportunity; Quadrant ❹ is a highly undesirable state that suggests significant action is warranted. The following scatter plot of facilities provides an example of the application of the condition-energy matrix, where the horizontal axis reveals the relative condition of the facilities and the vertical axis returns their energy efficiency.

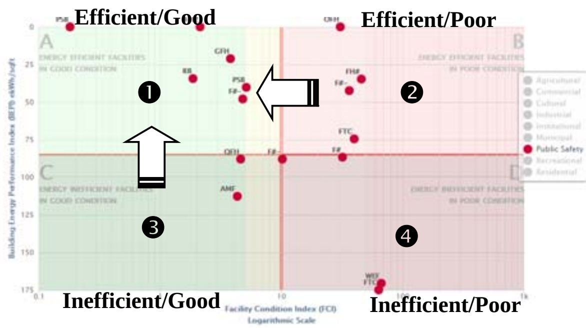

Figure 10: The condition-energy matrix

For example, swimming pools and ice arenas are higher energy consumers than fire halls and police stations. However a high energy use intensity does not necessarily imply a poor energy performer. The strategic focus for the facilities in each of the four quadrants is as follows:

❶	Ongoing routine maintenance to sustain performance over the long-term
❷	Decision choice: a) Repair, renewal and restoration; or b) sale/redevelopment.
❸	Ongoing routine maintenance with measured implementation of energy efficiency measures
❹	Decision choice: a) Repair, renewal, restoration; or b) sale/redevelopment.

The goal of the facility management group is to move facilities from quadrant ❷ to ❶ (by implementing ECMs and backlog maintenance reduction) and from Quadrant ❸ to ❶ (by implementing ECMs).

5.3 The Condition-Priority Matrix

This matrix plots the relationship between the relative condition of the facilities and their criticality to the owners' mission. Facilities within the portfolio will fall into one of the four quadrants are as follows:

❶	High priority buildings in good condition	✓
❷	High priority buildings in poor condition	✗
❸	Low priority buildings in good condition	✓
❹	Low priority buildings in poor condition	?

Quadrant ❶ represents a desirable state; Quadrant ❷ is an undesirable state; Quadrants ❸ and ❹ represent opportunities for the portfolio management team.

In the following scatter plot, the horizontal ('x') axis includes the condition and the vertical ('y') axis represents the increasing mission criticality of the facilities.

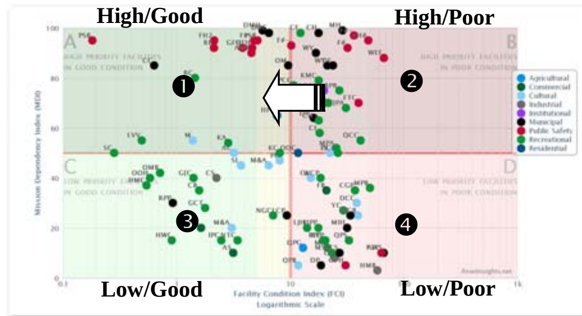

Figure 11: The condition-priority matrix

For example, fire halls (identified in red) are often deemed mission critical and occupy the top band of the quadrant. The strategic focus for buildings in each of the four quadrants are as follows:

❶	Business as usual - Routine maintenance and adequate replacement reserve planning. These facilities should not be permitted to drift.
❷	Significant repair, renewal and restoration.
❸	Business as usual – routine maintenance and moderate replacement reserve planning. These facilities may be permitted to drift.
❹	Run to failure? Re-designation?

This matrix is one of the more intuitive matrices for the facility managers. Some of the challenges arise from the complexities and subjectivity in assigning a relative priority to facilities. For example, the parks and recreation department will debate the value of their facilities compared to libraries and cultural. The goal of the facility management group is to move facilities from quadrant ❷to ❶ (and from Quadrant ❹ to ❸).

6 The Patterns

Each of these scatter plots can be analysed in a variety of ways. With reference to municipal portfolios, these averages, deltas, trends and copulas can be further evaluated.

6.1 By Civic Department

Municipal portfolios are organized into different departments, including parks & recreation, libraries and cultural, fire department, and police services. During the annual budget planning cycles it is helpful to ascertain the relative condition of the group of facilities within each department so that resource allocations can made on the basis of departmental needs for a particular fiscal cycle.

6.2 By Geographical Region

A geographically distributed portfolio can be organized into different regions on the basis of factors such as climate zones, seismic zones and regulatory environments. This can have a tremendous influence on decision making in some circumstances. For example, it may be a critical consideration that reinvestment is not prudent for older facilities in seismic zones since these should be redeveloped instead.

6.3 By Function

In a municipal portfolio, some of the buildings may be designated to perform as post-disaster facilities. For example, a gymnasium may be a muster station and an ice arena may be intended for food storage or a morgue. These secondary designations have strategic implications for the decisions about ongoing sustainment of the facility, irrespective of the age of the facility. An aged ice arena could have significant value as a post-disaster facility that may far exceed its utility as a recreational facility.

6.4 By Time Horizon

The rate of change within a portion of the portfolio will help establish trajectories for the future. For example, an aging portfolio of indoor swimming pools (say, 30+ years) may be deteriorating at a faster rate than a department of young fire halls (say, <15 years).

6.5 By Ownership/Interest Structure

Some municipalities and commercial landlords hold a portion of their property portfolios in leasehold interests and freehold ownership. The scatter plots reveal where the portfolio manager should address the "deferred maintenance" in the freeholds and the "permissive wasting" in the leaseholds (under the terms of the triple-net lease agreements). The optimal ratio of freehold-to-leasehold properties will vary between portfolio groups and perhaps also at different times within the same portfolio, particularly as needs change over the years and decades.

7 Deeper (Multivariate) Analysis

While each of the bivariate scatter plots (matrices) have tremendous value, particularly in isolating the relationships between key attributes, they are limited in a number of ways:

- They provide only one facet of a multi-faceted story, which therefore represent only one slice of a more holistic picture.
- Portfolio managers do not have the time or resources to search for deeper connections between each of the bivariate analyses. Multivariate analysis is beyond the reach of simple spreadsheets and requires sophisticated software and modelling that.
- Portfolios are not homogenous and have tremendous variability in the function and performance of facilities within different departments.

In seeking ways and means to analyse additional variables, two solutions were considered: a) a graphical representation of the data; and b) a tabular representation of the data.

7.1 Multivariate Analysis in Graphical Form

The authors developed a 3-dimensional image (cube) that draws in another variable to permit deeper analysis and insight. The figure below provides a conceptual example of a 3-dimensional multivariate analysis, which is limited, in this example, to three attributes (condition, energy efficiency and capital costs).

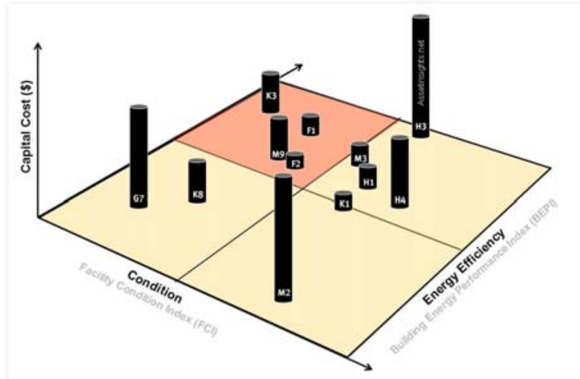

Fig. 12. A sample of a 3D matrix to visualize the correlation between three attributes

A number of limitation present themselves in the graphical format: a) Software currently restrict the ability to model multiple variables in a visual medium; b) only three or four variables can be modelled at the same time using colour to distinguish the fourth variable; c) the multitude of data points on the graphs clouds the presentation and, therefore, only a small number of facilities can be effectively reviewed and cognitively recognized at the same time; and d) the image needs to be properly rotated in order to distinguish the base point of each facility.

7.2 Multivariate Analysis in Table Form

After developing and testing different 3D images, the authors developed a rank score system to derive a multivariate analysis that returns a more accessible summary of the data. This form of multivariate pulls together the attributes, via algorithm, into a table. Included below is an example of how each of the isolated variables are aggregated in reference to each facility in the portfolio.

Facilities	**Value for the "Age" attribute**	**Resultant score for "Age" attribute**
Fire Hall #6	31 years	7.2 points
Ice Arena #41	18 years	9.9 points
Swimming pool #16	9 years	6.9 points
Museum #3	85 years	4.0 points

A more complete version of the tool is provided in figure 13 on the following page. Each row identifies individual facilities (such as fire hall #6), each column identifies the values and scores (points) on the corresponding attributes (such as facility "age"). Each attribute has a value that returns a score.

While the authors have continued to use the 3D images to help communicate some of the concepts to municipal managers and city councils, the rank score method has demonstrated itself as a more powerful tool for alignment with the City's finance department.

	A																		
	Attributes and Scoring																		
	1		3		4		5		6		7		13		16				
	Age		Reproduction Cost		MDI		Catchup Costs		5-Yr Keepup Cost		30-Yr Keepup Costs		Date of Last FCA		Energy Use Intensity (EUI)		Redevelopment	Building Score	Rank
Weight	10		0		30		30		15		5		15		5			110	
Building	years	Score 0-10	$/sqft	Score 0-10	0-100	Score 0-10	% FCI	Score 0-10	% EFCI - FCI	Score 0-10	$ Capital Load	Score 0-10	Year	Score 0-10	kWh / sqft	Score 0-10		Score 0-100	
Building 13	31	7.18	$197.04	6.62	92	9.20	14.63%	9.99	19.66%	9.72	$1,872,210	10.00	2012	8.27	154.40	9.80		92.42	1
Building 80	46	4.81	$169.78	6.13	90	9.00	16.76%	9.92	18.66%	9.82	$2,067,700	1.22	2014	9.56	60.00	5.56		85.46	2
Building 43	16	9.60	$126.77	5.20	74	7.40	14.37%	9.98	25.01%	8.07	$2,018,040	10.00	2010	5.31	123.10	9.00		83.02	3
Building 26	12	8.40	$109.04	4.75	77	7.70	9.35%	8.58	5.34%	5.85	$10,423,100	10.00	2012	8.27	69.80	6.25		78.67	4
Building 52	57	4.22	$187.97	6.46	98	9.80	8.35%	8.03	10.75%	9.19	$8,780,450	2.23	2010	5.31	148.10	9.69		77.67	5
Building 12	39	5.54	$184.84	6.41	97	9.70	28.18%	6.11	28.45%	5.96	$2,698,250	10.00	2012	8.27	154.40	9.80	★	76.57	6
Building 35	11	7.98	$209.15	6.82	90	9.00	10.48%	9.09	3.82%	4.44	$704,790	3.64	2010	5.31	154.40	9.80		75.99	7
Building 68	72	3.88	$288.04	7.86	68	6.80	12.91%	9.81	18.35%	9.84	$2,380,710	6.59	2010	5.31	85.10	7.22		75.75	8
Building 11	29	7.98	$197.66	6.63	70	7.00	9.24%	8.52	46.37%	4.00	$1,817,900	10.00	2012	8.27	154.40	9.80		75.31	9
Building 39	12	8.40	$101.47	4.55	72	7.20	11.65%	9.50	5.13%	5.67	$712,212	10.00	2010	5.31	60.00	5.56		75.22	10
Building 27	18	9.90	$201.04	6.69	47	4.70	8.60%	8.17	8.27%	7.98	$4,016,160	10.00	2012	8.27	235.60	9.01		74.91	11
Building 96	39	5.54	$467.21	9.12	40	4.00	18.45%	9.83	21.88%	9.34	$1,723,600	6.80	2014	9.56	85.10	7.22		74.89	12
Building 36	32	6.90	$153.59	5.80	95	9.50	28.20%	6.10	21.89%	9.33	$2,328,340	1.09	2010	5.31	154.40	9.80	★	73.74	13
Building 17	22	9.90	$216.81	6.94	79	7.90	8.21%	7.94	30.63%	4.96	$13,576,110	1.13	2012	8.27	69.80	6.25		73.61	14
Building 06	53	4.38	$86.29	4.12	40	4.00	10.63%	9.15	16.49%	9.93	$3,225,290	10.00	2012	8.27	235.60	9.01		73.31	15
Building 64	72	3.88	$285.76	7.83	70	7.00	12.56%	9.74	7.06%	7.20	$478,750	5.45	2010	5.31	148.10	9.69		73.10	16
Building 04	39	5.54	$445.14	9.02	98	9.80	7.96%	7.79	4.28%	4.89	$4,306,812	9.91	2009	3.70	85.10	7.22		72.51	17
Building 72	32	6.90	$208.78	6.81	55	5.50	13.73%	9.93	28.19%	6.11	$3,678,990	10.00	2010	5.31	69.80	6.25		71.30	18
Building 58	36	6.01	$228.84	7.12	52	5.20	16.58%	9.92	11.82%	9.55	$5,696,150	1.95	2010	5.31	85.10	7.22		71.14	19
Building 14	18	9.90	$181.80	6.35	95	9.50	2.25%	2.78	28.13%	6.14	$3,332,500	10.00	2012	8.27	154.40	9.80		71.13	20
Building 15	40	5.41	$200.17	6.67	93	9.30	4.63%	5.21	40.37%	4.02	$2,103,390	10.00	2012	8.27	154.40	9.80		70.25	21
Building 08	21	9.98	$224.92	7.06	99	9.90	1.27%	1.61	16.75%	9.92	$14,177,820	1.16	2012	8.27	148.10	9.69		70.19	22
Building 88	36	6.01	$232.54	7.17	50	5.00	8.07%	7.87	24.26%	8.46	$1,751,628	4.66	2014	9.56	69.80	6.25		70.09	23
Building 34	45	4.89	$180.97	6.34	64	6.40	16.23%	9.93	7.50%	7.50	$285,250	1.25	2010	5.31	60.00	5.56		69.55	24
Building 19	24	9.60	$179.14	6.31	72	7.20	2.64%	3.21	11.98%	9.59	$2,372,040	10.00	2012	8.27	69.80	6.25		68.87	25
Building 66	52	4.43	$163.95	6.01	50	5.00	9.25%	8.53	13.08%	9.83	$4,521,260	6.58	2010	5.31	235.60	9.01		68.65	26
Building 73	11	7.98	$259.88	7.53	92	9.20	3.73%	4.34	5.13%	5.67	$2,224,200	10.00	2010	5.31	154.40	9.80		68.16	27
Building 07	20	10.00	$178.66	6.30	30	3.00	20.95%	9.54	45.61%	4.00	$2,025,960	10.00	2012	8.27	85.10	7.22		67.84	28
Building 09	17	9.78	$118.86	5.01	98	9.80	2.42%	2.97	38.16%	4.05	$7,323,810	10.00	2012	8.27	60.00	5.56		67.57	29
Building 51	52	4.43	$176.48	6.26	63	6.30	13.17%	9.85	5.06%	5.61	$3,062,010	3.74	2010	5.31	69.80	6.25		67.50	30
Building 32	32	6.90	$127.76	5.22	75	7.50	4.48%	5.08	25.21%	7.96	$13,908,030	10.00	2010	[illegible]	[illegible]	[illegible]		[illegible]	31
Building 79	37	5.84	$288.07	7.86	95	9.50	2.13%	2.64	4.21%	4.82	$826,103	7.59	2014	9.56	154.40	9.80		65.91	32
Building 22	37	5.84	$178.65	6.30	20	2.00	15.38%	9.95	25.38%	7.86	$630,240	2.27	2012	8.27	148.10	9.69		65.34	33

B	
Variables	
4	5
MDI Score (MDI/10)	Acceptable FCI
MDI	FCI
0	40%
1	30%
2	20%
3	10%
4	8%
5	7%
6	5%
7	4%
8	3%
9	2%
10	2%

Redevelopment Variables	
Age >	30
Year 1 + FCI >	50%

	C				
	Threshold Funding $ 10,274,861				
	5	6			
	Catchup	5-Yr Keepup	Expenditure	Building Score	Rank
				110	
Building	Score 0-10	Score 0-10		Score 0-100	
Building 13	2.49	9.72	$ 151,500	71.95	2
Building 80	2.49	9.82	$ 327,544	65.20	17
Building 43	4.62	9.58	$ 143,200	70.45	4
Building 26	4.62	5.86	$ 294,000	67.89	10
Building 52	2.49	9.20	$ 706,004	62.55	30
Building 12	2.49	5.98	$ 603,000	66.71	11
Building 35	2.49	4.33	$ 84,540	57.83	52
Building 68	5.56	9.84	$ 307,675	64.16	22
Building 11	4.62	4.00	$ 74,800	64.68	21
Building 39	4.62	5.47	$ 27,200	61.64	34
Building 27	7.82	7.80	$ 29,700	73.71	1
Building 96	7.82	9.33	$ 297,900	69.41	7
Building 36	2.49	9.37	$ 615,540	63.94	23
Building 17	4.62	5.33	$ 719,150	65.05	18
Building 06	7.82	9.93	$ 41,800	69.69	6
Building 64	4.62	7.20	$ 62,874	59.15	45
Building 04	2.49	4.90	$ 846,000	58.06	51
Building 72	7.16	6.11	$ 204,923	63.74	24
Building 58	7.16	9.55	$ 671,369	63.59	25
Building 14	2.49	6.37	$ 12,600	70.66	3
Building 15	2.49	4.03	$ 43,100	62.83	29
Building 08	1.61	9.92	$ -	70.19	5
Building 88	7.16	8.46	$ 27,717	68.15	9
Building 34	5.56	7.44	$ 35,100	57.52	54
Building 19	3.21	9.51	$ 4,200	68.76	8
Building 66	7.16	9.84	$ 165,868	64.91	19
Building 73	2.49	5.67	$ 26,964	63.10	27
Building 07	8.89	4.01	$ 149,900	66.08	14
Building 09	2.49	4.05	$ 31,000	66.27	13
Building 51	5.56	5.61	$ 350,750	55.79	61
Building 32	4.62	8.01	$ 58,660	64.88	20
Building 79	2.49	4.82	$ 1,893	65.52	15
Building 22	9.95	7.86	$ -	65.34	16

	D				
	Available Funding $ 4,000,000				
	5	6			
	Catchup	5-Yr Keepup	Expenditure	Building Score	Rank
			$ 4,000,000	110	
Building	Score 0-10	Score 0-10		Score 0-100	
Building 13	2.49	9.72	$ 151,500	71.95	5
Building 80	2.49	9.82	$ 327,544	65.20	27
Building 43	4.62	9.58	$ 143,200	70.45	9
Building 26	4.62	5.86	$ 294,000	67.89	19
Building 52	2.49	9.20	$ 706,004	62.55	34
Building 12	2.49	5.98	$ 603,000	66.71	23
Building 35	2.49	4.33	$ 84,540	57.83	57
Building 68	5.56	9.84	$ 307,675	64.16	30
Building 11	4.62	4.00	$ 74,800	64.68	29
Building 39	4.62	5.47	$ 27,200	61.64	39
Building 27	7.82	7.80	$ 29,700	73.71	1
Building 96	7.82	9.33	$ 297,900	69.41	15
Building 36	2.49	9.37	$ 615,540	63.94	31
Building 17	6.24	5.33	$ 337,397	69.45	14
Building 06	9.15	9.93	$ -	73.31	2
Building 64	9.74	7.20	$ -	73.10	3
Building 04	7.79	4.89	$ -	72.51	4
Building 72	9.93	6.11	$ -	71.30	6
Building 58	9.92	9.55	$ -	71.14	7
Building 14	2.78	6.14	$ -	71.13	8
Building 15	5.21	4.02	$ -	70.25	10
Building 08	1.61	9.92	$ -	70.19	11
Building 88	7.87	8.46	$ -	70.09	12
Building 34	9.93	7.50	$ -	69.55	13
Building 19	3.21	9.59	$ -	68.87	16
Building 66	8.53	9.83	$ -	68.65	17
Building 73	4.34	5.67	$ -	68.16	18
Building 07	9.54	4.00	$ -	67.84	20
Building 09	2.97	4.05	$ -	67.57	21
Building 51	9.85	5.61	$ -	67.50	22
Building 32	5.08	7.96	$ -	66.07	24
Building 79	2.64	4.82	$ -	65.91	25
Building 22	9.95	7.86	$ -	65.34	26

Fig. 13. An excerpt from the multivariate matrix correlation tool for a portfolio

8 The Rank Score Algorithm

The multivariate decision-support tool is a table representation of the pertinent facility attributes (age, size, etc.) selected from a master group of 18 attributes based on a particular type of portfolio, each scored (1-10), and weighted (0-30) to return a ranking of facilities (1, 2, 3…) prioritized for the distribution of available funds. The facilities are then re-ranked based on the results of those resource allocations.

8.1 Four Step Methodology

The multivariate table, an excerpt of which is included in Figure 13, is organized into four parts (A through D) as follows:

- ***A.*** ***Attributes & Scores***. The 1st section of the table includes the score for each facility prior to the distribution of funds. These scores culminate in the pre-allocation ranking.
- ***B.*** ***Criticality Thresholds and Variables.*** The 2nd section contains the "filters" through which the scores are moderated for sensitivities to match different portfolio objectives. The thresholds serve to establish the allowable standard of care for a facility within the corresponding mission criticality ranking. The variables also include validation for which facilities should potentially be considered for redevelopment.
- ***C.*** ***Threshold Funding Results.*** The 3rd section of the table includes the scores resulting from allocation of funding to ensure that the FCI for all the facilities in the portfolio meets the criticality thresholds. For example, the reduction of the backlog of deferred maintenance to the target level at all facilities within a single fiscal year.
- ***D.*** ***Limited Funding Results.*** The 4th section of the table returns the ranked scores resulting from a fixed, limited funding level in the current fiscal cycle. The funds are allocated down the table, based on the relative scores, until the available funds are exhausted.

The table allows for different threshold sensitivities within the same portfolio.

8.2 Criticality Factors & Standards of Care

Based on the deemed mission criticality for each facility, a corresponding maximum FCI is deemed allowable**.** To this end, the following table indicates the range of FCI thresholds utilized as the variables in the sample portfolio.

Mission Dependency Index **(MDI)**	Acceptable Facility Condition Index **(FCI)**
0-9	40+% - critical condition
10-19	30% - poor condition
20-49	10% - good condition
50-59	5% - good condition
60-79	3% - good condition
80-100	2% - good condition

Based on the target standards of care and tolerance for risk, the portfolio managers must establish the level of deficient conditions that are considered acceptable. While there are industry standards that provide some measure of guidance on the appropriate thresholds to be selected, each portfolio team should consider adjusting the sensitivities to their corporate mission.

8.3 Weighting Distributions & Sensitivity

The different weightings are distributed across the attributes to reflect their relative sensitivities to funding inputs. The following table illustrates the weightings employed at two different types of portfolios ("1" Municipal and "2" Commercial) and based upon the significance of the return on investment deemed by the two portfolio management teams.

	Selected Attributes (quantitative & qualitative)	**Weightings for Portfolio "1"** (Municipal)	**Weightings for Portfolio "2"** (Commercial)
1	Age of Facility	10	20
2	Size of Facility	0	10
3	Cost of Reproduction New (CRN)	0	5
4	Mission Dependency Index (MDI)	30	0
5	Backlog of Deferred Maintenance (FCI)	30	20
6	Capital Load, Tactical Horizon (next 5 years)	15	10
7	Capital Load, Strategic Horizon (next 30 years)	5	5
13	Date of last assessment (FCA)	15	5
14	Post-Disaster Designation (PD)	25	0
15	Revenue generation & lease income	0	30
16	Energy Use Intensity (EUI) & Building Energy Performance Index (BEPI)	5	5
18	Obsolescence susceptibility (FNI)	0	10

In reference to Portfolio "1", which contains municipal facilities, the Mission Dependency Index (attribute #4) is critical and deemed to be six times more important than the capital load of the facility (attribute #7). Portfolio "2" is commercial in nature and does not contain facilities that operate in the public interest; therefore, the MDI (attribute #4) is set to zero but the revenue generating potential (attribute #15) is essential to financial sustainability and set at multiplier of 30.

It must be recognized that some of the attributes are quantitative and cannot be changed by the owner, such as facility age and size. Other attributes, however, are qualitative and can be manipulated by the owners, to varying degrees, such as catch-up costs (FCI), energy consumption (EUI) and mission dependency index (MDI), particularly through the infusion of financial capital or re-designation of mission criticality (MDI).

Some of the attributes are highly sensitive to resource allocations and can be influenced immediately (the same fiscal year) while others are only impacted gradually over time (several years or decades).

8.4 Pre-Allocation Rankings

Once the portfolio management team has accepted the weightings, they are provided with a ranked order of all the facilities. The following table draws an extract from Figure 13 to illustrate the aggregated points and the resulting ranking before funds are distributed.

Facilities	**Aggregated Score**	**Ranking** (before)
#13 Fire Hall	92.42 points	1
#80 Ice Arena	85.46 points	2
#43 Swimming Pool	83.02 points	3
#26 Museum	78.67 points	4
…	…	…
#09 Animal Shelter	12.02 points	193

The preceding table displays the facilities from highest to lowest rank, with the highest scores receiving capital infusion sooner so as to address the capital needs assessment. In this case, the fire hall (facility 13) has returned 92.42 points, whereas the museum (facility 26) scored 78.67 points and is ranked 4th.

Facilities percolate to the top of the ranking based on their aggregated scores. In some cases, mission critical facilities that are in good condition will occupy a lower position than a less critical facility in poor condition. In other cases, a facility in good condition, and requiring minimal capital infusion, could rank higher than a facility in poor condition requiring significant capital infusion.

8.5 Post-Allocation Rankings

The post allocation rankings can be evaluated in accordance with to two funding measures; both of which provide the proposed dispersion of funds across the facilities for the ensuing fiscal year.

- ***Threshold Funding*** - This answers the question "*How much money will I need to keep my FCI in line with the standard of care we have selected?*"
- ***Available Funding*** - This answers the question "*What will be the resultant FCI based on my available funding of "x"?*

While threshold funding may be an ideal-type scenario, it is useful to gauge the quantum of the funding shortfall relative to the available funds. The next table indicates the updated ranking after fund are distributed in a manner that keeps the facilities at a minimum acceptable FCI level.

Facilities	**Aggregated Score**	**Ranking** (after)
#13 Fire Hall	71.95 points	2
#80 Ice Arena	65.20 points	17
#43 Swimming Pool	70.45 points	4
#26 Museum	67.89 points	10
…	…	…
#09 Animal Shelter	17.34 points	193

In the available funding approach, the portfolio manager works down the ranking list and applies funds consecutively until the funds are exhausted.

9 Resource Allocation Decisions

The efficacy of the multivariate resource allocation tool varies relative to the four decision points referenced at the outset of the paper.

9.1 Decision: Reinvestment-or-Redevelopment

A decision on whether to continue to reinvest in the sustainment of an existing facility or to redevelop a new facility relies upon the integrated analysis of several attributes, but principally: FCI, FNI, MDI, age and functional obsolescence. Recognizing that this is a formidable decision for municipal managers, with far reaching implications, the multivariate resource allocation tool includes some variables in the filter portion of the table. To this end, a "star" appears on the table if the combined value of the deferred maintenance (catch-up costs) and 10-year capital load (keep-up costs) is greater than a threshold of the CRN (say, 50%) and the age of the facility is greater than a certain number of years (say 35 years).

Further development of the multivariate decision-support tool requires a means to quantify different degrees of functional obsolescence and translate this into a numerical value to be included with the aggregate scores for each facility. Numerical quantification of functional obsolescence has been attempted for certain classes of facilities but not yet been sufficiently developed.

9.2 Decision: Adaptive-or-Like Renewal

When faced with the choice between energy efficiency measures (EEMs) or facility renewal measures (FRMs) the multivariate decision tool can be used to evaluate the impact of resource allocations across the portfolio. Since EEMs result in lowering the energy use intensity (EUI) of the facility, this particular attribute would be re-weighted to a higher amount. By changing the multiplier, the EUI modification has a greater impact on the facility rankings.

Further development of the multivariate decision-support tool would include more precise quantification of the impact of energy efficiency measures on the actual energy use intensity of facilities. Standardization of the energy modelling of different classes of facilities is underway across the world.

9.3 Decision: Run-to-Failure or Just-in-Time Renewal

Limited resources result in managers making decisions to consciously (or unconsciously) allow certain facilities to degrade further while other facilities receive the capital. The multivariate resource allocation tool allows for adjustments to the Mission Dependency Index (MDI) and allowable Facility Condition Index (FCI) to differing thresholds so as to mitigate against the risk associated with increasing levels of deferred maintenance accumulating at individual facilities and condition drift collectively across the portfolio of the "neglected" facilities.

Further development of the multivariate decision-support tool requires an elegant deterioration model to more accurately track the path of asset degradation along the P-F curve, which extends from potential failure ("P") to functional failure ("F") and thereby reduce the risks associated with Just-in-Time Replacement strategies [3].

9.4 Decision: Freehold-or-Leasehold Interest

Decisions regarding the purchase of a freehold property or execution of a lease agreement will depend primarily on the term of the lease and the lessee responsibilities under the typical triple-net arrangement. The most critical attribute within the multivariate resource allocation tool is the capital load matched to the proposed lease period. For example, a lease of 10 years will obligate the portfolio management team to consider capital costs associated with asset renewals over that same period. Any shortcomings in the municipality's standard of care may result in "deferred maintenance" in its freehold properties, which corresponds with "permissive wasting" in a leasehold interest.

Further development of the multivariate decision-support tool requires research on how to mitigate the impact of portfolio politics, where vested interests of different municipal departments propose the weightings to be attached to each of the qualitative facility attributes, particularly those attributes that rely on different appraisals of real estate value.

10 Closure

The challenges of retiring the infrastructure deficit, at a pace that exceeds the ongoing condition drift in municipal portfolios, will continue to pose a significant hurdle for asset stewardship programs. The multivariate resource allocation tool in this paper contributes to the growing arsenal of asset management tools and provides additional information to improve the line-of-sight from the expenditure of each dollar spent on individual facilities to their resulting capital needs ranking within the portfolio.

Many portfolio managers find themselves having to operate on gut feel due to a lack of multivariate insight into their portfolio. While many years of experience working within a portfolio provides a powerful understanding of the performance of the portfolio overall and the anticipated trajectory of each facility, the corporate memory is lost each time there is a change in management.

The multivariate decision support tool provides a more objective measure to form part of a compelling business case to present to City Council for approval each fiscal cycle. It aalso serves as a benchmarking tool for tracking and re-evaluating the impact of resource allocation decisions over the ensuing years, despite periodic changes in the composition of the portfolio management team.

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