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Strategic retrofit investment from the portfolio to the building scale: a framework for identification and evaluation of potential retrofits

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Abstract

Buildings account for approximately 40% of the total energy consumption and associated GHG emissions globally. Within this sector, approximately 80% of buildings in North America are more than 15 years old and in the intervening years, energy codes have been revised to require 25% less energy than buildings meeting 2000 codes. As a result, even sustainably-rated buildings over 10 years old tend to compare poorly with new buildings built to minimum code standards. Significant investment is required to bring the performance of these buildings in line with market expectations and competition for newer, more sustainable buildings. In large portfolios, the challenge is not only to identify the optimal building retrofits, but also which buildings have the most improvement potential.

This paper presents a three step approach to overcome this challenge. First, the building portfolio is screened from the often limited available data and potential energy improvement potential and commercial improvement potential are ranked to identify priority buildings. Second, a series of retrofit bundles is tested on the priority buildings to calculate estimated energy savings, required capital and resultant operating costs and qualitative indicators affecting occupant comfort to prepare a financial analysis. These estimates are refined using an energy model for the most promising retrofit bundle. Finally, portfolio - wide strategies are developed for the non-priority buildings to take advantage of "low hanging fruit".

Four global case studies using this framework are presented, two at the portfolio scale and two at the building scale. In each case, the evaluation tools and techniques, modeling approaches and data used in this decision-making are described and resulting project recommendations are presented. Although developed primarily for commercial buildings, this approach is applicable to all building types and recommendations are offed for its adaptation across sectors.

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Keywords: sustainability; energy efficiency; building retrofits; asset management; strategic investment; portfolio analysis

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1. Introduction

In light of the increasing impact of building carbon emissions [1,2] and the increasing market demand within the real estate market for improved building sustainability [3-5] , the fundamental challenge facing portfolio owners is how to prioritize investment in their existing building stock and target the right buildings with the right degree of retrofit. The framework presented in this paper is focused on addressing this problem, considering both the commercial improvability and potential for energy and operational savings.

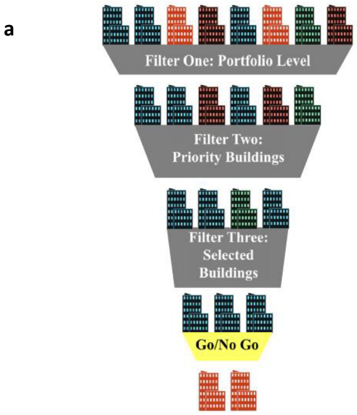
This paper presents a summary of the portfolio optimization tool and references four global case studies, providing representative model output and overall results; the first two demonstrate the sorting of larger portfolios, while the latter demonstrate the high-level optimization of the renovations for priority buildings.

Nomenclature

η	equipment efficiency
C	cost
COP	coefficient of performance
E	energy
elec	(subscript) from all electrical sources excluding heat
ENV_L	% building envelope life elapsed
ENV_X	building envelope type constant based
EUI	current energy use intensity (with subscript 90 indicates model ideal baseline)
GHG	greenhouse gas emissions
heat	(subscript) from all heat sources
H_x	HVAC system constant based on system type
H_L	% HVAC life elapsed
I_x	rental rate
IRR	internal rate of return
L_x	lighting system type constant
L_L	% lighting life elapsed
M_x	market favourability for the asset class
N_j	number of non-heating end uses
N_k	number of heating energy sources
N_Q	number of qualitative indicators
N_R	number of risk indicators
NPV	net present value
O_L	Occupancy duration (expected ownership or lease term with renewal(s) as appropriate)
O_R	Occupancy rate
O_x	Occupancy type (type of lease)
Q_i	qualitative score of bundle i
Q_P	performance for a given qualitative indicator
R_P	performance for a given risk indicator
R_C	current Capitalization Rate (measure of future income risk)
R_i	risk score of bundle i
W	weighting factor (indicated by subscript)
X_{TOT}	overall rating score for a bundle

2. Framework Description

This process consists of three steps, referred to as "filters", are used to differentiate the portfolio into disparate components for action, as indicated in Figure 1a. The first stage (Filter 1) sorts the portfolio into four quadrants and identifies the "priority" buildings to be further explored. Filter 2 investigates each of the priority buildings separately and evaluates the business-as-usual approach as well as four levels of retrofit of increasing CapEx and occupant disruption to identify the most appropriate level of investment in a building. Finally, Filter 3 optimizes the retrofit of each of the selected buildings and develops a calibrated energy model and market-verified cost estimate to inform a go-no/go decision on the optimized retrofit. These stages are described in detail in the following sections.



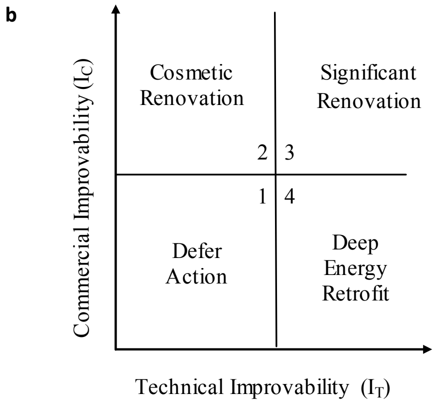


Fig. 1. a) Framework Filter Process and b) Quadrants for Portfolio Sorting

2.1. Filter 1: Portfolio Sorting and Building Prioritization

Filter 1 sorts the portfolio into four sets: those buildings where both commercial and energy performance can be dramatically improved, which are Priority Buildings to be further explored in Filter 2; those where the commercial improvability is low but deep energy retrofits using published building energy optimization approaches [6] are recommended; those where a cosmetic upgrade can re-classify an asset but the energy saving potential is limited; and those buildings where significant investment is not recommended at the present time. In order to do this, the overall improvement potential of a building is evaluated along on two axes; the y-axis indicates a normalized commercial improvability score (I_c) representing the relative potential for improving asset value, ranging from 0 for no potential and 1 for maximum potential, and the x-axis indicates a normalized technical improvability score (I_T) representing relative achievable energy or CO_2 savings on a similar scale. The mathematical models underlying these scores are indicated in Equations (1) and (2) below. Note that the "prime" for the I_c terms designates the post-retrofit condition.

$$I_c = W_I * \frac{I'_x}{I_x} * \frac{M'_x * \frac{O'_c}{R'_c}}{M_x * \frac{O_c}{R_c}} + W_{GHG} * \frac{GHG}{GHG_{max}} + W_{OCC} * \frac{O_L}{O_{L\,max}} * O_x \tag{1}$$

Depending on the client, the weighting factors for income, carbon emissions and lease (W_I, W_{GHG} and W_{OCC}) are adjusted to reflect corporate goals. For example, investor/owners or developers will weigh W_I heavily, owner/occupiers and tenants with high CO_2 reduction targets would rate W_{GHG} heavily, while tenants will also consider their lease duration and type and weigh W_{OCC} more heavily. Where a variety of stakeholders are engaged, this becomes increasingly complex [7] and this weighting, along with the balance of economic, qualitative (comfort), and risk approaches described in Section 2.2 aim to address this issue. The total of these three weighting factors must sum to 1. M_x values are based on historical building performance and range from 0 (worst) to 1 (best), based on expert input; typically a real estate specialist who could evaluate the regional, sub-regional and local comparables for a particular building within the larger market dynamics context and quantify the potential for commercial repositioning.

The building technical improvability, I_T, is defined in Equation 2, which adjusts the current energy use savings achieved by improving performance to the energy use intensity (EUI) of a 90th percentile building, adjusted for the technical and financial challenges to achieve these savings. The approach is similar to that proposed by Menassa et al [8] but is conducted as a desk study using rules of thumb at this stage of analysis.

$$I_T = (EUI - EUI_{90}) * (W_H * H_x * H_L + W_L * L_x * L_L + W_{ENV} * ENV_x * ENV_L) \tag{2}$$

End of life constants range from 0 for new elements to 1 for elements at or beyond their expected end of life and the weighting factors sum to 1 All remaining constants are based on historical building performance and range from 0 (worst) to 1 (best). Based on these results, buildings are addressed in one of four ways, indicated in Figure 1b.

No action is taken for buildings with relatively low improvability on both scales (Fig. 1b, quadrant 1). Buildings in this class fall are typically either top-rated assets with little room to improve, or severely challenged buildings, and thus have limited scope for improvement for opposite reasons. These buildings are thus typically excluded from further work, with the possible exception of energy conservation measures that can be implemented across a portfolio at no- or low-cost.

Buildings with higher commercial improvability but low technical improvability (Fig. 1b, quadrant 2) benefit most from cosmetic renovations to reposition the building in the market and achieve payback through rental uplift, and energy improvements are typically limited to low/no-cost items due to minimal predicted savings in operational costs.

Buildings with low commercial improvability but high technical improvability (Fig. 1b, quadrant 4) present a business case for deep energy retrofits due to older and easier-to-upgrade systems; however, there is limited potential to reposition the asset, which limits the value uplift based on net operating income and not to an asset class upgrade.

Finally, buildings ranking highly on both scales (Fig. 1b, quadrant 3) benefit most from substantial renovations, taking advantage of the opportunity to both reposition the asset and to dramatically improve the energy performance. These are the "Priority Bu ildings" and are further evaluated using Filter 2.

2.2. Filter 2: Identifying the Region of Optimization

This second stage evaluates a series of retrofit bundles with increasing investment to reflect different market positioning outcomes to identify the best level of investment. These bundles are designed to explore substantially different approaches to the building retrofit, and typically include the following: a baseline case, consisting of the replacement of equipment within 3 years of the end of life with the same type and capacity, removal of interior partitions, repair of any damaged finishes, and re-painting. a "light touch" and adds no-cost/low-cost energy conservation measures such as lighting upgrades, controls system reprogramming, re-commissioning and similar measures to the baseline. Bundle 2 is typically designed to increase the building rating and adds cosmetic elements to the preceding bundles, as well as retrofit of HVAC systems. Bundle 3 is designed to achieve the most common sustainability certification while completing the cosmetic work from Bundle 2. Bundle 4 is the most extreme, upgrading HVAC systems to premium efficiency, renovating and re-cladding to achieve a Class A/AAA building rating and a significantly higher rating under the prevalent sustainability certification.

To evaluate the energy savings for each building, utility bill normalization is undertaken exogenously, as is the energy modeling of the potential savings from energy conservation measures (ECMs) in each bundle. Once the energy usage has been calculated by usage type, the energy is separated into two components for further analysis: building heat demand and building electrical demand (for all non-heating end-uses). This approach allows the model to account for both differential costs and cost escalation as well as greenhouse gas emissions for alternative heating energy sources. Time-of use billing and hourly usage can be assigned varying costs; which can also be modeled using commercially-available software for building energy modeling. The total annual energy costs (Eq. 3) and greenhouse gas emissions (Eq. 4) are thus calculated.

$$C_{energy_i} = C_{heat_i} + C_{elec_i} = \sum_{j=1}^{N_j} E_j * \sum_{t=1}^{N_t} C_{elec_t} + \sum_{k=1}^{N_k} \frac{E_{heat_{i_k}}}{\eta_{i_k}} * C_{source_k} \tag{3}$$

$$GHG_i = GHG_{elec_i} + GHG_{heat_i} = \sum_{j=1}^{N_j} E_j * GHG_{elec_j} + \sum_{k=1}^{N_k} \frac{E_{heat_{i_k}}}{\eta_{i_k}} * GHG_k \tag{4}$$

Additional annual costs modeled include carbon taxes for incremental emissions, and operational and maintenance costs. Ongoing income sources are also included, such as revenue or offset cost from on-site renewable energy generation, rental income or equivalent saved rent. One-time costs, such as the capital costs for each bundle and energy efficiency incentives, as well as tenant allowance costs for leased spaces are also considered. These remaining cost inputs are also determined exogenously, using detailed cost estimates and construction scheduling as well as market research for leased properties. The full model derivation will be published in a future journal article.

The model requires adjustment to account for the change in the delay before rent can be collected/saved from the baseline value, and since these may vary between bundles, this must be calculated for each. The incremental net present value of each bundle compared with the baseline cases is then calculated and compared to determine the incremental benefit of each bundle. The incremental annual cash flow for each bundle and net present value of each renovation bundle is then calculated to provide a quantitative score for each bundle. This quantitative analysis is complemented by a qualitative analysis, whereby N_Q qualitative indicators affecting the occupant experience are evaluated for each bundle. Qualitative performance is calculated based on the product of a priority weighting factor (0 (low) $\leq W_P \leq 1$ (high)) and a performance rating (-3 (poor) $\leq Q_P \leq 3$ (best performance)).

$$Q_i = \frac{\sum_{q=1}^{N_Q} W_{p_q} * Q_{P_q}}{N_Q} \quad (5)$$

Finally, an opportunity and risk analysis is undertaken by repeating this qualitative analysis technique for a series of risk factors, using a similar approach to that indicated in Eq. 5, except that Q_i becomes R_i and C_P is replaced by a resiliency factor C_R that quantifies how well the risk exposure can be limited in a particular bundle (Eq. 6).

$$R_i = \frac{\sum_{r=1}^{N_R} W_{p_r} * R_{P_r}}{N_R} \quad (6)$$

Finally, the potential as-is sale cost is compared with sell vs lease/occupy scenarios for each bundle. Only bundles with positive financial performance are considered for the remainder of the analysis. The optimized level of retrofit is thus identified based on a total evaluation, X_{tot}, (Eq. 7) considering qualitative, risk and financial indicators as indicated below, where the weightings for each of the ratios (W_Q, W_R and W_c) are determined in consultation with the end client for the analysis. Any building with a positive total evaluation is subject to a go/no-go analysis and the bundle with the highest total evaluation score sets the region of optimized investment for future analysis in Filter 3.

$$X_{TOT_i} = W_Q * \frac{Q_i}{Q_{\max}} + W_R * \frac{R_i}{R_{\max}} + W_C * \frac{NPV_i}{NPV_{\max}} \quad (7)$$

2.3. Filter 3: Optimal Retrofit Identification and Business Case Development

The third level of analysis repeats Filter 2 within a much smaller region of evaluation where optimization techniques are used to evaluate variations on the retrofit within this region. A calibrated hourly building energy model is created to more accurately predict the energy savings for each variation and identify the optimum retrofit. Finally, a schematic design for the optimum bundle is developed and a detailed cost estimate is undertaken in consultation with industry experts and the model is then re-run with this data.

3. Case Studies

Four global case studies are introduced in this section with summary results for each, and sample data inputs and model outputs are provided for each filter. Comprehensive input data and results will be published in an upcoming publication. To protect confidentiality, all buildings are referred to by country and numerical identifier only.

3.1. Case Study A: Data and Methodology

This study involved a large global tenant with 40 properties in their UK portfolio and goals to reduce portfolio carbon emissions by 50% between 2007 and 2017. In the first five years, they reduced their emissions on an area basis by 33% through relocating offices to improved facilities, retrofits and occupant behavior initiatives. The study's intent was to identify the best opportunities in the portfolio to achieve the remainder of the goal. The portfolio was pre-screened to eliminate those that were being vacated (9 No.) and one not operational. Historic energy use data provided was supplemented by a one-hour walk through of the remaining 30 buildings to perform a high-level assessment.

The commercial improvability score considered 80% weighting on building percent contribution to CO_2 emissions and 20% on lease type (Figure 2). Lease duration was excluded as all properties were likely to be renewed except as determined by this study. Technical improvability focused on the EUI for each building (Figure 2), adjusted with systems scores favoring HVAC (75% weight) and lighting (25% weight). System ages were based on building age and renovation records and were typically 1, except for buildings undergoing renovation (#17) or newly-occupied (#1). Lease type was fundamental in addressing improvability, with factors assigned as-follows: For owned properties, O_x=H_x=L_x=1; for head lease properties, O_x= L_x=1 and H_x=0.8; for multi-tenant properties, O_x= H_x=0.3 and L_x=0.5, while for sub-tenancies, O_x=H_x=0 and L_x=0.25. The sorted portfolio is indicated in Figure 3a.

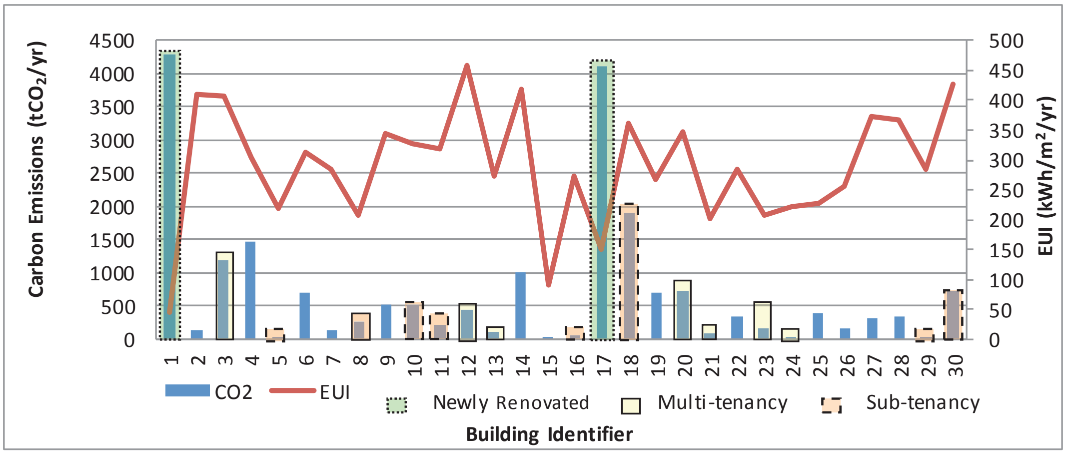


Fig. 2 Carbon emissions (bars), EUI (line) and lease type (shaded blocks overlaid on data) for Case Study B

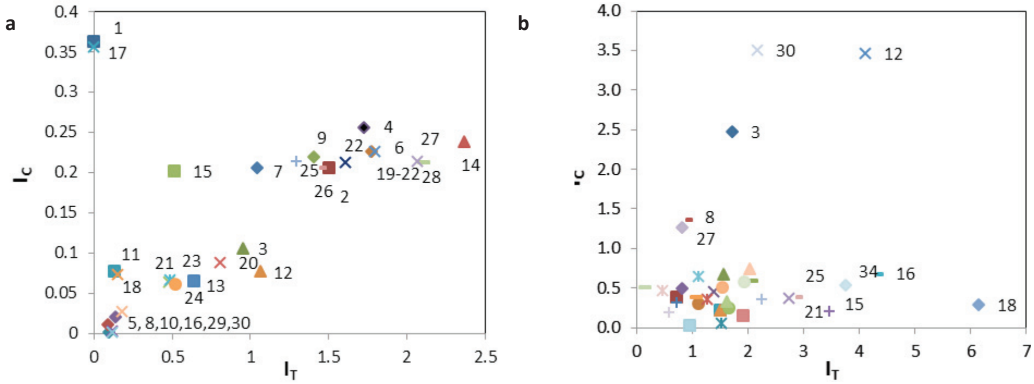


Fig 3. Sorted Portfolios: a) Case Study A; b) Case Study B

3.2. Case Study B: Data and Methodology

A university with 99 buildings over five campuses in the UK had an identified goal to reduce CO_2 emissions by 35% between 2010 and 2020 to align broadly with the Carbon reduction targets set by the Higher Education Funding Council for England [9]. A pre-screening of the buildings was done based on data availability and size; 51 were eliminated on a size basis (<1000m^2 (10,000sf) gross floor area), and 14 had inadequate building data for analysis, resulting in a revised pool of 34 buildings. CO_2 emission reductions were paramount for this project and dictated the commercial improvability (W_{CO2}=1) as all buildings were owned and not income properties. For technical improvability, the weighting factors on the EUI ratio were 60% HVAC, 20% lighting and 20% envelope. A complication in this study was the presence of listed buildings (#10 and 33), and for these, H_x=0.3, L_x=0.8, and ENV_x=0.1 were used to reflect the challenge of modifying the HVAC and envelope systems. For other pre-1945 buildings, ENV_x=0.2 and H_x=0.5 were used to account for the challenge of construction, while post-war building system factors were set to 1. The sorted portfolio is indicated in Figure 3b.

3.3. Case Study C: Data and Methodology

This project involved a single building (33,000sf low-rise Class B/B+ office) in a Canadian suburb. Given an upcoming end of lease, this building was pre-selected for retrofit by the client and analysis was undertaken to determine the most cost-effective renovation given a 20-year lease period and minimum acceptable IRR of 8%. As a preliminary step, the filter 1 methodology was applied: market analysis indicated that a green premium on rent was expected if an upgrade to a Class A office rating could be achieved with a minimum Energy Star score of 69. Many building elements were at or approaching the end of their useful lives (H_L=1, ENV_L=0.5 and L_L=0.8) and systems were relatively easy to upgrade (H_X=.8, ENV_X=0.5, and L_X=0.8), resulting in I_T=7.19 when the system weightings were 50% HVAC, 30% lighting and 20% envelope.

A sell-only case was considered where a minimal cost ($5/sf) was allowed for interiors demolition, along with four lease cases: the baseline representing the minimum required for re-lease, bundle 1 pursuing low-cost, high-benefit energy and water conservation measures, bundle 2 minimizing energy use intensity, bundle 3 combining a commercial upgrade with minimized operating costs, and a commercial upgrade targeting LEED® Existing Building certification and including on-site renewable energy generation. Capital and operational costs and energy consumption estimates for each bundle were calculated exogenously and each bundle was analysis as described in Section 2.2.

The bundles are described as-follows, and the results are summarized in Table 1.

- Baseline: demolition of the previous tenant layout, replacement of worn finishes, replacement of end-of-life rooftop units and repairs to the roof, including both new membrane and insulation to code minimums.
- Bundle 1: baseline plus low-flow flush and flow fixtures and a lighting upgrade from T12 to T8 lamps.
- Bundle 2: bundle 1 plus change to high-efficiency air-source heat pump rooftop units (EER>14.5, degree-day weighted average COP of 2.5) and replacement of baseboards with electric reheat coils.
- Bundle 3: bundle 1, cosmetic renovations (lobby and washroom renovations and upgraded ground floor tiles) plus gas-fired domestic water heater to replace the existing electric, two gas fired boilers and hot water VAV zone heaters to replace the electrical baseboard heaters, and rooftop HVAC units revised to indirect gas-fired heating. This bundle was based on a suggestion from a prospective, but non-committal, tenant.
- Bundle 4: bundle 2 and cosmetic renovations per Bundle 3, plus 10kW roof-mounted photovoltaic system

3.4. Case Study D: Data and Methodology

This case study involved a 38,415sf two-story commercial Class C office in a Canadian suburb, built circa 1950, and prioritized due to a unique floor plate and extremely high utility costs, combined with an imminent end of lease. Selling the land for redevelopment was believed to be the only option considering a low risk tolerance by the owner combined with a minimum IRR of 9%. This study was to determine whether there were any renovation approaches that could justify maintaining ownership of the building over a 10-year lease period.

Table 1. Case Study C: Quantitative Bundle Analysis.

Quantitative Indicator	Sell as-is	Baseline Case	Bundle 1	Bundle 2	Bundle 3	Bundle 4
Capital Expenses	165k	717k	737k	817k	1,152k	1,068k
Construction cost ($/m^2)	$5	$234	$240	$266	$376	$348
Construction Period	n/a	2 months	3 months	3 months	4 months	3 months
Potential Vacancy Period	24 months+	24 months	23 months	22 months	14 months	12 months
Annual Utility Costs ($/yr)	153k	144k	139k	117k	108k	114.5k
Annual Maintenance Costs ($/yr)	$249k	$249k	$249k	$249k	$249k	$249k
Energy Usage (MWh/yr)	865	863	811	674	824	657
Energy Usage Intensity (kWh/sf/yr)	26.2	25.0	24.6	20.4	24.6	19.9
Annual CO_2 emissions (tCO_2/yr)	50	50	49	41	88	40
Water Usage (l/m^2/yr)	16.4	16.4	16.1	13.4	28.9	13.1
Potential Energy Star Rating	48	50	53	68	54	70
20-yr incremental NPV	N/A	0	205k	811k	704k	1,224k

Market analysis indicated that the local market was saturated and there was substantial local competition from both Class A and Class B office properties. Absorption periods locally were 693 days for single-tenancies and the local market vacancy rate was 18.5%; more than twice that of the region, resulting in low commercial improvability without investment beyond the client's stated limits. Technically, the HVAC systems were at or approaching their end of life (H_L=1), the building envelope required minor repairs (ENV_L=0.25) and lighting had already been partially upgraded (L_L=0.2). The constant-volume dual-duct HVAC system could not be modified without full replacement and other systems were not easily upgraded (H_X=0.1, ENV_X=0.3, and L_X=0.1). Weighting 50% HVAC, 40% lighting and 10% envelope and an ideal EUI of 15kWh/sf/yr resulted in I_T=0.297, recommending low-cost system modifications only.

Two sale cases (as-is to owner/occupier or sale for redevelopment) were considered along with four bundles: a baseline case representing the minimum required for re-lease, a light touch bundle for single-tenant occupancy, a commercial upgrade for single-tenant occupancy, and two additional bundles (light touch and commercial upgrade) for multi-tenant occupancy.

The scope of these are defined as:

- Baseline: installation of new elevator and four barrier-free washrooms to meet accessibility requirements, plus demolition of previous tenant layout, replacement of ceiling and carpeting in non-renovated areas, repainting, $250,000 allowance for entry/lobby renovation, replacement of low-flow washroom fixtures, repair of external paving, replacement of 7 cast-iron boilers and existing hot water heater with new, and re-commissioning of building controls and systems
- Bundle 1 (Single-tenant light touch): baseline plus building controls upgrade, repaving of parking lot, stain removal from facade and a lighting upgrade (remaining T8 to T5 lamps) including daylighting controls.
- Bundle 2 (Single-tenant market upgrade): bundle 1 plus restoration of underground parking lot functionality (was used as storage space), recladding of building with composite metal panels, finishes upgrade throughout, solarfective coating on windows, washroom renovation and provision of dedicated server rooms to facilitate tenant IT upgrades.
- Bundle 3 (Multi-tenant light touch): bundle 1 plus a demising partition on the ground floor to allow subdivision of that floor and reclassification of connecting corridors between the north and south buildings as common spaces
- Bundle 4 (Multi-tenant market upgrade): bundle 2 plus demising partition and corridor reclassification, plus $75,000 allowance for entrance canopy at side entrance

Capital and operational costs and energy consumption estimates for each bundle were calculated exogenously and each bundle was analyzed as described in Section 2.2. The data and quantitative results for all bundles is summarized in Table 2.

Table 2. Bundle Analysis for Priority Building (Case 4, Suburban Canada).

Quantitative Indicator	Sell	Baseline Case	Bundle 1	Bundle 2	Bundle 3	Bundle 4
Capital Expenses	$0	$1,873k	$2,628k	$5,376k	$2,679k	$5,461k
Construction cost ($/m^2)	$0	$42.90	$60.50	$127.90	$61.80	$130.00
Construction Period (months)	N/A	6	6	6	6	6
Expected Vacancy Period	6 months+	18 months	18 months	16 months	12 & 18 months	10 & 16 months
Annual Utility Costs	$170k	$166k	$100k	$102k	$100k	$102k
Annual Maintenance Costs	$296k	$296k	$296k	$296k	$296k	$296k
Energy Usage (MWh/yr)	2,620	2,096	1,552	1,578	1,552	1,578
Energy Usage Intensity (kWh/sf/yr)	68	57	42	43	42	42
Annual CO_2 emissions (tCO_2/yr)	343	269	204	205	204	205
Water Usage (l/m^2/yr)	336	285	285	285	285	285
Potential Energy Star Rating	1	2	16	15	16	15
10-yr incremental NPV	N/A	0	400k	-1530k	650k	-1460k
Building Value (post-retrofit sale)	$730k/$2,420k	$680k	$1,210k	-$920k	$1,460k	-$700k

[*]730k is the building net value for sale to an owner/occupier, while $2,420k is the expected net value for demolition and sale of the land for redevelopment

Summary of Recommendations

In Case Study A, the buildings recommended for Filter 2 analysis were those with I_C>0.2 and I_T>1.4, i.e. buildings 4, 6, 9, 14, 19, 22, 27, and 28. System upgrade bundles were identified and a high-level analysis of these buildings to inform a full Filter 2 analysis has since been carried out.

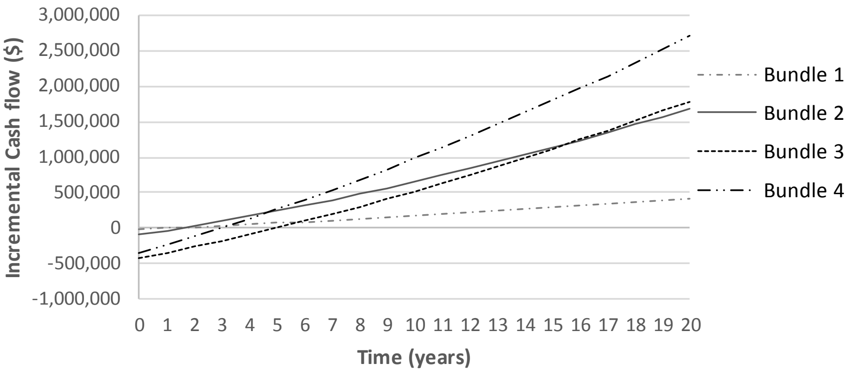


Fig. 4. Case Study C: Bundle Incremental Cash Flow Analysis

Case Study B Buildings with I_C>2 (#3, 12 and 30) were the top priority buildings and scheduled for the first set of retrofits, along with #2, 8, 9, 11, 21, 23, 27 and 29. The modeled cash flow predictions for Case Study C are indicated in Figure 4. Based on net present value, Bundle 4 provided the best return on investment, whereas both the qualitative and risk assessments favored Bundle 3. Because of the client's desire to avoid risk, this immediate sale was also presented as an option. The recommended course of action for Case Study D was to sell for redevelopment as it provided the optimal financial performance for the client while minimizing risk exposure, and was the implemented strategy.

4. Recommendation to Adaptation to Non-Commercial Buildings

The model as it stands applies well to non-commercial buildings when the rental income is replaced with the cost of occupying equivalent space, and the commercial improvability scale is revised to reflect the value of the building's location to the owner/occupant. For example, for an industrial facility, proximity to transit and supply chain partners as well as number of employees present and their productivity would be key factors would be considerations. For a healthcare or educational facility, the catchment area would be a critical factor in the decision of whether or not the building was in a location that warranted long-term investment. The detailed application of this model to these applications is beyond the scope of these proceedings, and will be elaborated upon in future publications.

5. Conclusions

This paper has presented a proven mathematical model to address the challenge of identifying the most strategic investments to make within a building portfolio. First, "priority buildings" are identified within the portfolio based on commercial and technical improvement potential. Next, the appropriate level of investment is determined for each priority building by testing a series of renovation bundles and analyzing each, considering financial, qualitative, and risk factors simultaneously.

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