COMPARATIVE ECONOMICS OF MEMBRANE STRUCTURES

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INTRODUCTION

In choosing between alternative roofing systems each possible option has to be measured by its aesthetic and technical value and by its economic justification. Much has been written about the architecture and engineering of membrane structures, but the perception remains that they are an expensive alternative.

The cleanability, reflectivity, translucency and durability of membrane structures are all properties that make them an attractive alternative t what are sometimes considered to be conventional solutions.

This paper attempts to set out simple methods for the comparison of such alternatives taking into account all relevant advantages and disadvantages.

TIME VALUE OF MONEY

Just as money increases with time by earning interest, so every cash flow after the time of original investment should be reduced to account for this "time value" when considering different investment strategies.

For example, if a present sum of money (P), say $100, was invested at interest rate i, say 12%, for one year, the future value for this present sum would be

$$F = \$100 + 0.12 \times \$100 = \$112$$

If this were then reinvested, its value at the end of the second year would be

$$F = \$112 + 0.12 \times \$112 = \$125.44$$

or $$F = (\$100 + 0.12 \times \$100) + 0.12 \times (\$100 + 0.12 \times \$100)$$

$$\begin{aligned} F &= (P + i \times P) + i \times (P + i \times P) \\ &= P \times (1 + i) + (i \times P) \times (1 + i) \\ &= P + iP + iP + Pi^2 \\ &= P\,(1 + i)^2 \end{aligned}$$

which is equivalent to: $F = (1 + i)^2$

The general formulae for single amounts earning interest over time (n) is $F = P\,(1 + i)^n$

This can be algebraically rejuggled to give the present value of a future expenditure

$$P = F\,(1 + i)^{-n}$$

For recurring cash flows the present value (PV) of these is the sum of all individual cash flows discounted for their time value.

$$PV = \sum_{0}^{n} F\,(1 + i)^{-n}$$

In the case of membrane structures, consideration must be given to concept stage of all future cash flows that will modify the perceived cost of possible alternatives.

These will include:

- maintenance
- lighting
- heating and cooling
- operating costs (air structures)

TAX EFFECTS

These expenditures need to be further modified due to Tax effects. Most operations (especially private sector) with a taxable income are taxed at some rate (Tx) which reduces this income and thereby modifies cash flows.

Net Income = Taxable Income x (1 - Tx)

Similarly, if money (C) that would otherwise be taxable is spent in a way that reduces taxable income the cash flow of that expenditure should be modified in a way that reflects this reduction in tax liability.

Expense amount after tax = C x (1 - Tx)

Maintenance expenditures would fall into this category and would therefore be offset by a tax saving on the original amount, if however a tax saving is realised without the expenditure of money at the time, then the cash flow is the amount of actual taxes saved :-

Cash Flow = Non-cash expense x (Tx)

DEPRECIATION

Capital assets lose value over time due to deterioration and obsolescence. This gradual loss of an assets value is known as depreciation and can be treated as an annual expense charged against earnings before taxes during the useful life of the asset. In general, the faster an asset can be depreciated the greater the present value of the depreciation and tax savings. For this reason accelerated methods of depreciation are preferred. For membrane structures it may be justifiable to have a different depreciation period than for other types of structure.

The summation of the depreciation expense charges must be discounted to zero date by the use of this and the previous Present Value Formulae combined.

USING PRESENT VALUES

When all such factors are considered for alternative roofing and enclosure systems the initial view of a membrane roof being the most costly may be proved wrong. The same analysis can be used when comparing different types of membrane structures :- for example air structures vs framed supported structures.

The Present Value Formulae are available on computer spreadsheet programs (eg LOTUS 123) and these can be readily used to calculate the present value of a forecast stream of future cash flows and hence compare on an equal basis very different investment strategies.

Example 1. Swimming Pool Enclosure

Given that an enclosure can be justified against the "do nothing" option, we compare for a 25 m pool a 30m x 30m enclosure:-

Option 1. Membrane structure on steel frame at $\$450/m^2$ capital cost.

Option 2. Conventional steel framed building with internal linings and artificial lighting at $\$350/m^2$ capital cost

		OPTION 1	*OPTION 2*
CAPITAL COSTS		$405,000.00	$315,000.00
OPERATING COSTS	BUILDING MAINTENANCE	$5,000.00	$10,000.00
(in the first year	LIGHTING	$2,500.00	$7,500.00
and increasing with	HEATING & COOLING	$17,500.00	$15,000.00
CPI thereafter)			
PRESENT VALUE OF:-	DEPRECIATION TAX SAVING	$62,710.68	$48,774.97
	MAINTENANCE COSTS	($35,925.82)	($71,851.64)
	ENERGY COSTS	($143,703.28)	($161,666.19)
TOTAL EQUIVALENT PRESENT VALUE		($521,918.43)	($499,742.86)

VARIABLES	
TAX RATE	39.00%
INTEREST RATE	15.00%
INFLATION RATE	10.00%
LIFE FOR DEPRECIATION	20 years
SALVAGE VALUE	$0.00

It can be seen from this that the initial $90,000 capital cost difference is markedly reduced to $22,000 when the maintenance, energy and depreciation cash flows are included in the calculation.

Example 2.

60m x 30m
Framed Membrane Structure vs. Air Structure

Air Structures are significantly cheaper in first cost than a frame supported structure, but cost more to operate and heat. Also their lifespan may be considerably shorter and erection/dismantling costs need to be taken into account.

Option 1. A frame supported membrane structure @$290/m² capital cost incl. foundations.

Option 2. Air Structure at $220/m² capital cost with a reduced depreciation period.

		OPTION 1	OPTION 2
CAPITAL COSTS		$522,000.00	$396,000.00
RUNNING COSTS	BUILDING MAINTENANCE	$5,000.00	$10,000.00
(in the first year	MECHANICALS	$1,000.00	$6,000.00
and increasing with	HEATING & COOLING	$10,000.00	$12,500.00
CPI thereafter)			
PRESENT VALUE OF:-	DEPRECIATION TAX SAVING	$80,827.09	$107,977.66
	MAINTENANCE COSTS	($35,925.82)	($71,851.64)
	ENERGY COSTS	($79,036.81)	($132,925.54)
TOTAL EQUIVALENT PRESENT VALUE		($556,135.53)	($492,799.52)
VARIABLES			
TAX RATE		39.00%	39.00%
INTEREST RATE		15.00%	15.00%
INFLATION RATE		10.00%	10.00%
LIFE FOR DEPRECIATION (years)		20	5
SALVAGE VALUE		$0.00	$0.00

The prime cost advantage of the air structure is reduced when all costs over a possible 20 year life are considered. This situation would deteriorate further if economic lifes were compared, but this is beyond the scope of the comparison technique used.

Example 3.

A supporting centre atrium 20m x 10m roof in a subtropical climate. Compare :-

Option 1. A Teflon coated roof at $500?m²

vs.

Option 2. Polycarbonate glazed roof at $350/m²

		OPTION 1	OPTION 2
CAPITAL COSTS		$100,000.00	$70,000.00
OPERATING COSTS	BUILDING MAINTENANCE	$1,000.00	$3,000.00
(in the first year	LIGHTING	$1,000.00	$2,160.00
and increasing with	HEATING & COOLING	$2,000.00	$4,200.00
CPI thereafter)			
PRESENT VALUE OF:-	DEPRECIATION TAX SAVING	$15,484.12	$10,838.88
	MAINTENANCE COSTS	($7,185.16)	($21,555.49)
	ENERGY COSTS	($21,555.49)	($45,697.64)
TOTAL EQUIVALENT PRESENT VALUE		($113,256.54)	($126,414.25)

VARIABLES	
TAX RATE	39.00%
INTEREST RATE	15.00%
INFLATION RATE	10.00%
LIFE FOR DEPRECIATION	20 years
SALVAGE VALUE	$0.00

The cleanability of the membrane roof, and the enhanced thermal and optical performances contribute to a superior economic position of this alternative.

INTERNAL RATE OF RETURN

If the analysis also requires that different incomes will be generated from the optional investment strategies, then those incomes can be included in the stream of future cash flows hence affecting the calculated Net Present Value of the investment.

The value of i at which the Net Present Value (including initial and future cash flows) of the investment equals zero is said to be the Internal Rate of Return (IRR) of the investment.

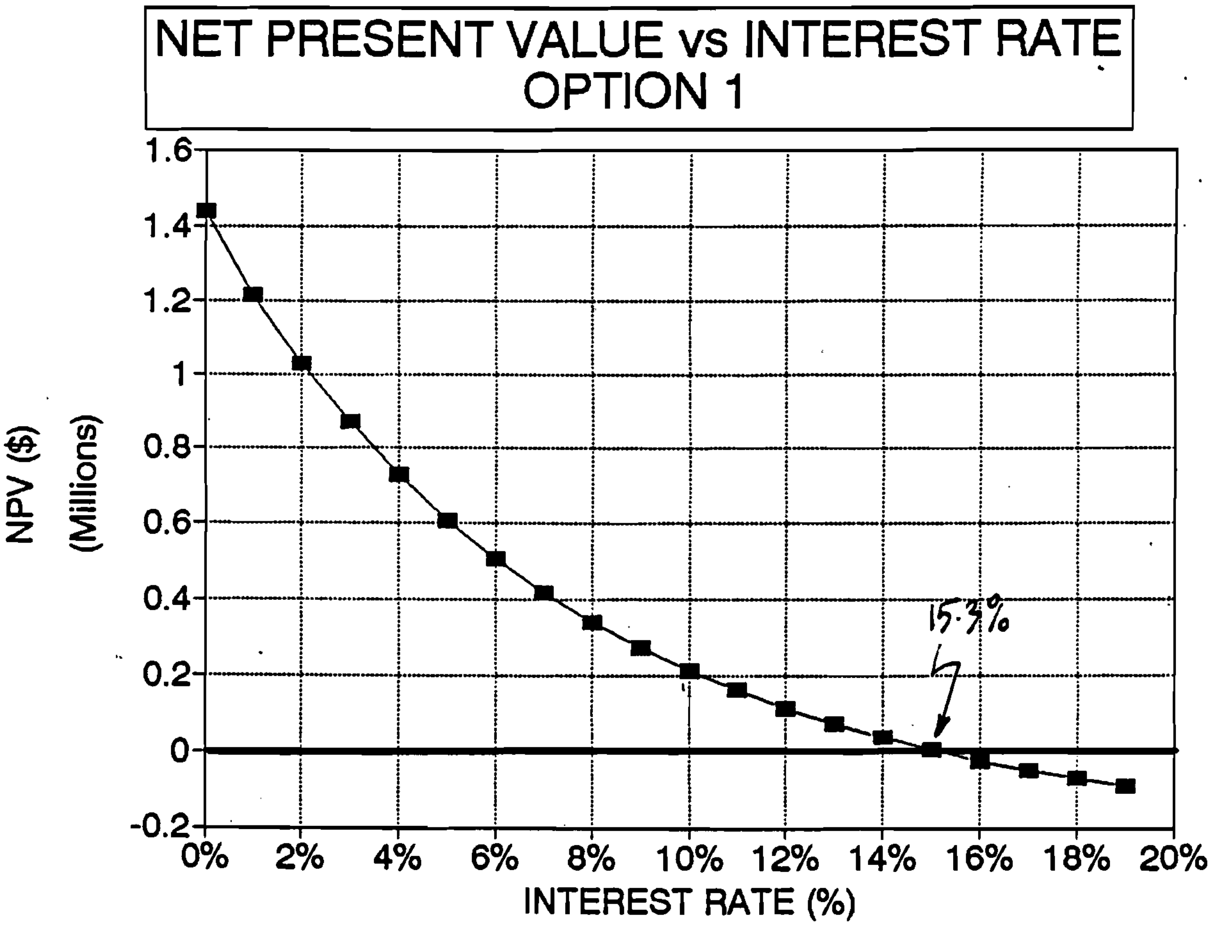

Figure 1.

Option 1 of Example 1 with initial income generated of $45,000 increasing with CPI for a considered life of 20 years. The IRR calculated is 15.2%

This is a useful measure as it expresses the profitability in percentage terms which is easily understood by all. Furthermore when the IRR is greater that the cost of capital the investment can be accepted.

IRR calculations are also available on spreadsheet programs. It is of course very important to remember the sign convention used ie. cash outflows are negative and incomes are positive.

Difficulties arise in using IRR to compare alternatives which are only part of an overall project as the income generated by each part cannot be easily separated from the whole.

However if the difference between the alternatives can be calculated for each cash flow, including all capital operating expenses as well as incomes then marginal cash flows can be given an internal rate of return which is the Rate of Return on the extra capital required.

Example 4.

This is example 1 revisited but with a small advantage in the income to the membrane structure alternative.

		OPTION 1	OPTION 2	2-1
CAPITAL COSTS		$405,000.00	$315,000.00	$90,000.00
RUNNING COSTS	BUILDING MAINTENANCE	$5,000.00	$10,000.00	($5,000.00)
(in the first year	LIGHTING	$2,500.00	$7,500.00	($5,000.00)
and increasing with	HEATING & COOLING	$17,500.00	$15,000.00	$2,500.00
CPI thereafter)				
INCOME PER ANNUM		$55,000.00	$52,000.00	$3,000.00
PRESENT VALUE OF:-	DEPRECIATION TAX SAVINGS			$13,935.71
	MAINTENANCE COST SAVINGS			$35,925.82
	ENERGY COST SAVINGS			$17,962.91
NPV OF SAVINGS ON TOTAL OUTLAYS				($22,175.56)
NPV OF MARGINAL INCOME				$35,336.87
				$13,161.31
INTERNAL RATE OF RETURN ON MARGINAL CAPITAL				19.8%

VARIABLES	
TAX RATE	39.00%
INTEREST RATE	15.00%
INFLATION RATE	10.00%
LIFE FOR DEPRECIATION	20 years
SALVAGE VALUE	$0.00

This shows an IRR on marginal capital of 19.8%. If this percentage is greater than the cost of the money then the investment is a good one. Even with no marginal improvement in income the IRR in this example would be 12.8% and is not dependant on the interest rate.

CONCLUSIONS

The techniques outlined in this paper can be used to compare membrane structures with competing systems on an equal basis. High initial capital costs can be offset by lower maintenance and energy costs and small increases in annual income can justify quite large capital expenditures.

The data needed to perform these calculations can only be obtained on a case by case basis, but in general will show membrane structures to be competitive on an economic basis if considered in the long term.