Overall Cost Analysis

A project is often defined by how much it costs or how much money it saves. There are many ways to determine these costs or savings, and the ones used on this project include the first costs, operating costs, and life cycle costs. Unfortunately, all too often project design decisions are driven solely by the first costs, and not their operating costs or life cycle costs. It will be shown here that the life cycle cost analysis is a much more important and valuable tool to define the bottom line of a project.

This section is broken down into smaller sub-sections. They include: first costs of the original mechanical system, new equipment first costs, operating costs for the new equipment, and the life cycle costs. For additional information and full life cycle cost analysis reports, please refer to Appendix L – Overall Cost Analysis.

First Costs of Original Mechanical Systems

In order to properly evaluate the effects of changing the mechanical systems and equipment in the Hilton Hotel at BWI Airport, the original equipment costs must be known. If cost estimates must be made, the calculations and data will not be nearly as accurate. Please see Table 53 – Original Mechanical Equipment Costs below.

Table 53 - Original Mechanical Equipment Costs

(288) Water-Source Heat Pumps	$430,000
(4) AHUs, (6) RTUs,(43) VAVs, (70') FTRs, and other equipment	$507,100
(2) Cooling Towers	$61,315
(2) Heat Exchangers	$31,810
(4) HW Boilers	$61,000
(23) Pumps	$33,686
(2) HW Generators	$46,430
(2) Water Heaters	$38,548
(43) Fans	$65,200
(5) Sump Pumps	$29,800
(1131) Diffusers	$26,971
(3) Valves and (3) Traps	$30,873
Plumbing Fixtures	$192,896
Sheetmetal Specialties	$25,785
Pipe Fitting Specialties	$17,418
Plumbing Specialties	$61,556
Misc. Equipment	$40,949
Grand Total	**$1,701,337**
Total Used	**$491,315**

The data and information required for the existing mechanical system first cost was provided by Southland Industries, Inc., who is the mechanical contractor for the Hilton Hotel at BWI Airport project.

The first costs can be broken down into several pieces. The sheet metal, pipe fitting, and plumbing all depend on their related costs for labor, materials, and fabrication. The mechanical equipment, which totals about $1.7 million, can be looked at in smaller categories indicating both quantity and prices of certain pieces of equipment. Other costs include the work being sub-contracted out, the start/test labor, and the general conditions fees. After totaling all of these costs together, the total mechanical system first cost was almost $6.5 million. The cost per square foot was found to be about $23.68/sf.

However, in order to compare the first costs of the existing mechanical systems and the new mechanical systems design, only the equipment costs are taken into consideration. This is because exact quantities of piping and ductwork with their corresponding costs for labor, materials, and fabrication were not determined for the new mechanical systems. The amount of sub-contracted work, the start/test labor, and the general conditions fees are also unknown. Many assumptions could be made about these things, but it is more accurate to only compare those items which have known values.

In addition to this, some of the equipment listed in Table 53 – Original Mechanical Equipment Costs is lumped together with other components. For example, the actual costs for the four AHUs and the six RTUs would be helpful in comparing the new selections to the original equipment. However, the AHUs and RTUs were lumped together with numerous VAV boxes, fin tube radiators, and other equipment.

Even though there are many difficulties with the provided equipment costs for the original system, only those costs that are know for sure will be used in the cost analysis. Those costs are for the 288 water-source heat pumps (WSHPs) and the two cooling towers. The equipment costs used from the original design are listed below in Table 54 – Original Equipment Costs Used for Analysis.

Table 54 - Original Equipment Costs Used for Analysis

Original Equipment Costs	
(288) Water-Source Heat Pumps	$430,000
(2) Cooling Towers	$61,315
Total	**$491,315**

New Equipment First Costs

Although they are not the most important factor in determining the life cycle costs, the first costs are still a major contributor. The following tables all show the first costs of the new mechanical equipment selected and used for study in this thesis project. Please note that none of the first costs for the necessary piping or ductwork was included in this analysis. These items would require proper sizing and measurement of lengths to determine their first costs. Only the equipment first costs were determined for this project.

Table 55 - Chiller First Costs

Option No	Manuf	Qty	Model	Misc	Price Ea	Total Price
1	Carrier	2	19XRV	10 F delta-T	$84,600	$169,200
2	York	2	MaxE	12 F delta-T	$112,500	$225,000
3	McQuay	2	WSC	12 F delta-T	$125,000	$250,000
4	McQuay	1	WDC-IGV	12 F delta-T	$196,500	$196,500
5	McQuay	1	WDC-VFD	12 F delta-T	$227,000	$227,000
6	Trane	1	CTV	12 F delta-T	$114,518	$251,704
6	Trane	1	CTV-AFD	12 F delta-T	$137,186	
7	Trane	2	CTV-AFD	12 F delta-T	$137,186	$274,372

Table 56 - Cooling Tower First Costs

Option No	Manuf	Model	Misc	Qty	Price Ea	Total Price
1	Marley	NC8305FL2	1200 rpm	2	$40,300	$80,600
2	Marley	NC8306EL2	1200 rpm	2	$46,150	$92,300
3	Marley	NC8305F2	1800 rpm	2	$39,000	$78,000
4	Marley	NC8307E2	1800 rpm	2	$47,450	$94,900

Table 57 - FCU First Costs

Option No	Manuf	Model	Qty	Price Ea	Total Price
1	Carrier	42S-300	128	$1,335	$170,880
1	Carrier	42S-400	160	$1,350	$216,000
2	Enviro-Tec	VHC-04	128	$1,850	$236,800
2	Enviro-Tec	VHC-04	160	$1,850	$296,000

Table 58 - Air Handling Unit First Costs

Option No	Manuf	Model	Qty	Price Ea	Total Price
1	Carrier	39MN-50	1	$30,100	$30,100
1	Carrier	39MN-40	1	$29,500	$29,500
1	Carrier	39MN-21	1	$17,600	$17,600
1	Carrier	39MN-12	1	$13,700	$13,700

Table 59 - Rooftop Unit First Costs

Option No	Manuf	Model	Qty	Price Ea	Total Price
1	Carrier	39MW-06	1	$17,600	$17,600
1	Carrier	39MW-30	1	$30,400	$30,400
1	Carrier	39MW-12	1	$20,400	$20,400
1	Carrier	39MW-06	1	$17,400	$17,400
1	Carrier	39MW-03	1	$16,000	$16,000

Table 60 - Dedicated Outdoor Air System Unit First Costs

Option No	Manuf	Model	Qty	Price Ea	Total Price
1	Semco	PVS-13	1	$90,193	$90,193
1	Semco	PVS-18	1	$102,993	$102,993

Table 61 - Pump First Costs

Option No	Manuf	Model	Qty	Price Ea	Total Price
1	Bell&Gossett	1510-5G	2	$8,389	$16,778
1	Bell&Gossett	1510-5BC	2	$6,986	$13,972

Table 62 - Heat Exchanger First Costs

Option No	Manuf	Model	Qty	Price Ea	Total Price
1	Bell&Gossett	P41	1	$28,150	$28,150

New Equipment Annual Operating Costs

One of the most important parts of the project costs are the annual costs. These are often related to the energy consumption and operating costs of the mechanical equipment, as well as the relative maintenance. Since this thesis design project is entirely theoretical, actual data for maintenance and replacement of equipment is unknown. Guesses could be made values could be estimated. However, this would not yield very useful results. Therefore, only the operating costs of the equipment related to the electrical and natural gas energy usage and costs are considered for the annual costs.

The following tables all show the energy usage and operating costs of some of the new mechanical equipment selected and used for study in this thesis project. Since only the chillers and cooling towers were studied to find the best option to be used in the new design with specific life cycle cost analyses, only the operating cost information for that equipment is shown in the tables below.

Table 63 - Chiller Energy Usage and Operating Costs

Option No	Manuf	Model	Qty	HAP Cooling Energy (kBtu)	HAP HVAC Energy (kBtu)	HAP Cooling Cost	HAP HVAC Cost
1	Carrier	19XRV	2	3,181,062	26,486,885	$73,875	$232,709
2	York	MaxE	2	3,452,357	26,682,921	$79,914	$237,094
3	McQuay	WSC	2	3,096,184	26,339,122	$71,685	$228,972
4	McQuay	WDC-IGV	1	3,500,117	26,730,690	$80,947	$238,114
5	McQuay	WDC-VFD	1	3,027,870	26,270,535	$70,774	$228,069
6	Trane	CTV	1	3,276,105	26,520,763	$75,078	$232,361
	Trane	CTV-AFD	1				
7	Trane	CTV-AFD	2	2,696,646	25,937,498	$62,655	$219,876

Table 64 - Cooling Tower Energy Usage and Operating Costs

Cooling Tower	No of Cells	HAP Cooling Tower Energy (kBtu)	HAP HVAC Energy (kBtu)	HAP Cooling Tower Annual Costs	HAP HVAC Annual Costs
NC8305FL2	2	525,710	27,243,670	$11,946	$248,391
NC8306EL2	2	395,166	27,113,125	$8,979	$245,422
NC8305F2	2	525,710	27,243,670	$11,946	$248,391
NC8307E2	2	395,166	27,113,125	$8,979	$245,422

The energy usage and operating costs could not be directly found using HAP. However, the annual component costs were compared for Option 1 (Carrier 42S FCUs) and Option 2 (Enviro-Tec VHC04 FCUs), and the total HVAC costs for Option 1 was $5 less than Option 2.

New Equipment Life Cycle Costs

The combination of the first costs and annual operating costs are used to evaluate the mechanical equipment for the Hilton Hotel at BWI Airport in the life cycle cost analyses. These analyses were done on several different items, including the chillers, cooling towers, and all the entire mechanical system. Carrier's Engineering Economic Analysis (EEA) program was used to do all the life cycle cost analyses since the inputs were straightforward and useful graphs and information was gathered easily from the results. A 20 year analysis period was used, and a minimum attractive rate of return (MARR) was assumed to be 8%. The escalation rate was used at 2%. This was assumed, but when compared to all other options at the same analysis period, it did not matter what MARR or escalation rate was used.

Chiller Life Cycle Costs

The life cycle cost analysis done on the chillers involved comparing the first costs and operating costs for seven different scenarios (Option 1 through 7). Option 1 had the lowest first cost, but Option 7 had the lowest operating costs. After the comparison was made, the life cycle costs were found to be the lowest for Option 7. A graphical representation of this can be seen below in Figure 17 – Chiller Life Cycle Cost Graphs.

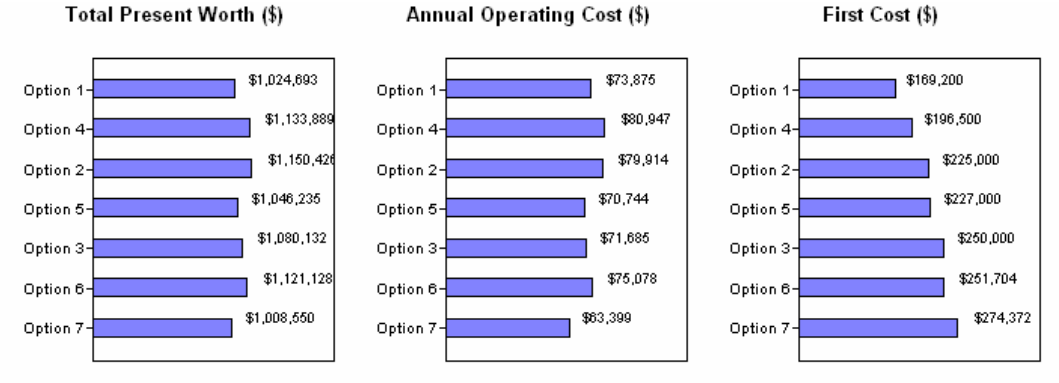

Figure 17 - Chiller Life Cycle Cost Graphs

Since Option 7 had the lowest life cycle costs, noted as the lowest total present worth, that chiller arrangement was chosen to be used in the BWI Hilton new mechanical system design. Please refer to the "Chillers" section previously described for more information about this design and selection process. The breakdown of all the chiller costs are listed below in Table 65 – Chiller Life Cycle Cost Breakdown.

Table 65 - Chiller Life Cycle Cost Breakdown

Design Case Name	Design Case Short Name	Total Present Worth ($)	Annual Operating Cost ($/yr)	First Cost ($)
Option 1 - (2) Carrier 19XRVs	Option 1	$1,024,693	$73,875	$169,200
Option 4 - (1) McQuay WDC w/ IGV	Option 4	$1,133,889	$80,947	$196,500
Option 2 - (2) York MaxEs	Option 2	$1,150,426	$79,914	$225,000
Option 5 - (1) McQuay WDC w/ VFD	Option 5	$1,046,235	$70,744	$227,000
Option 3 - (2) McQuay WSCs	Option 3	$1,080,132	$71,685	$250,000
Option 6 - (1) Trane CTV, (1) CTV-AFD (12F)	Option 6	$1,121,128	$75,078	$251,704
Option 7 - (2) Trane CTV-AFD (12F)	Option 7	$1,008,550	$63,399	$274,372

Cooling Tower Life Cycle Costs

The next life cycle cost analysis was done for the cooling towers. There were four possible options of cooling towers to be used on the BWI Hilton project. Two of the cooling towers had lower first costs and lower efficiencies (Options 3 and 4), and the other two cooling towers had higher first costs and higher efficiencies (Options 1 and 2). These four new options were also compared to the original cooling towers used, which was referred to as the Base Case.

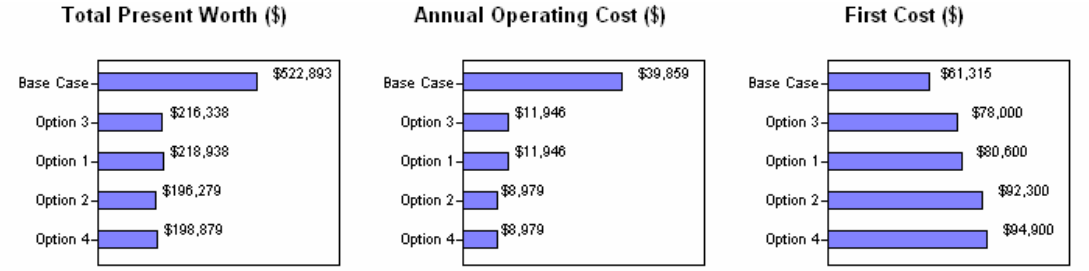

Figure 18 - Cooling Tower Life Cycle Cost Graphs

The graphical representation of the life cycle costs are shown above in Figure 18 – Cooling Tower Life Cycle Cost Graphs. All four of the new cooling towers being studied had significantly lower operating costs than the base case cooling tower, even though the base case had the lowest first cost. Option 2 had the lowest total present worth, so it was chosen to be used in the new mechanical system design. The breakdown of all the cooling tower costs is listed below in Table 66 – Cooling Tower Life Cycle Cost Breakdown.

Table 66 - Cooling Tower Life Cycle Cost Breakdown

Design Case Name	Design Case Short Name	Total Present Worth ($)	Annual Operating Cost ($/yr)	First Cost ($)
Base Case - Original Design	Base Case	$522,893	$39,859	$61,315
Option 3 - Marley NC8305F2	Option 3	$216,338	$11,946	$78,000
Option 1 - Marley NC8305FL2	Option 1	$218,938	$11,946	$80,600
Option 2 - Marley NC8306EL2	Option 2	$196,279	$8,979	$92,300
Option 4 - Marley NC8307E2	Option 4	$198,879	$8,979	$94,900

Mechanical System Life Cycle Costs

The final life cycle cost analysis was done on the entire mechanical system. The new mechanical systems design was compared to the original mechanical system base case for the Hilton Hotel at BWI Airport. A graphical representation of the two cases is shown below in Figure 19 - Mechanical Systems Life Cycle Cost Graphs.

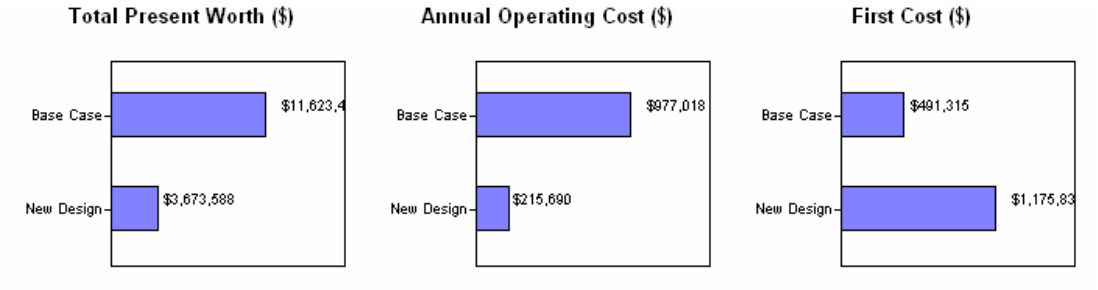

Figure 19 - Mechanical Systems Life Cycle Cost Graphs

It can clearly be seen that the base case had a much lower first cost than did the new design ($684,523). However, the annual operating costs of the new design were much lower than those for the base case ($761,328). This translated into a significant difference in the overall life cycle costs between the base case and the new design. The breakdown of all the mechanical system costs is listed below in Table 67 – Mechanical Systems Life Cycle Cost Breakdown.

Table 67 - Mechanical Systems Life Cycle Cost Breakdown

Design Case Name	Design Case Short Name	Total Present Worth ($)	Annual Operating Cost ($/yr)	First Cost ($)
Base Case - Original Design	Base Case	$11,623,441	$977,018	$491,315
Chilled Water Plant Design	New Design	$3,673,588	$215,690	$1,175,838
Difference	-	$7,949,853	$761,328	($684,523)
% Diff	-	68.40%	77.92%	-139.32%

A summary of all the life cycle cost results for the new design over the base case is shown below in Table 68 – New Design Life Cycle Cost Summary. The payback period was calculated to be 1.0 years, which is an extremely short period of time. Also, an internal rate of return over 100% is exceptionally high. A graph of the payback period can be seen in Figure 20 - Payback Period Graph.

Table 68 - New Design Life Cycle Cost Summary

Challenger	Base Case	Additional First Cost ($)	NPW Savings ($)	IRR (%)	Payback Period (yrs)
New Design [Winner]	Base Case	$684,523	$7,949,854	114.23	1.0

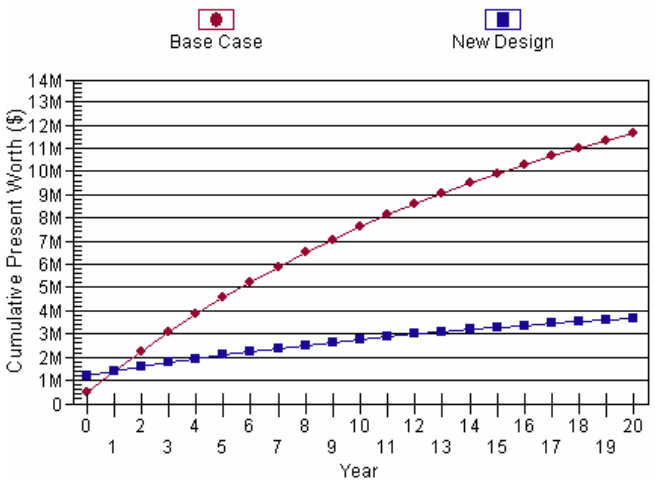

Figure 20 - Payback Period Graph

Overall Cost Analysis Conclusions

Several conclusions can be made about the life cycle cost analyses performed for the Hilton Hotel at BWI Airport. First, only life cost analyses were done for equipment that more than one possible choice during the design. For example, there were price quotes given for seven different chillers and four different cooling towers. The fan coil units had two quotes given, but direct annual operating costs could not be taken straight from HAP. Therefore, the overall system operating costs were used to compare these two items (but they only differed by $5). Since the operating costs were nearly identical, the first costs were used to determine which option to choose. All the other equipment selected to be used in the new mechanical systems design only had one price quote provided by the manufacturers. For this reason, no other equipment life cycle costs were calculated. Only the overall system life cycle costs were compared.

The overall system life cycle costs were drastically different. The first cost of the new design was about 2.4 times that of the base case. But the annual operating costs of the base case were 4.5 times that of the new design. This resulted in a very high internal rate of return and an extremely fast payback period of only one year. Please note that the results would change if the new piping and ductwork first costs and all the appropriate original equipment first costs were included in the analysis. However, this method was a good estimate.