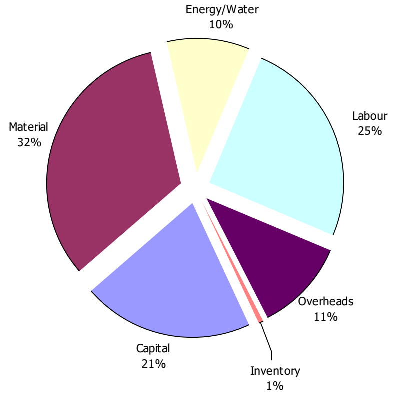
Life Cycle Cost Analysis: A Guide for Engineers

Dennis McCarthy DAK Consulting.

Engineers will recognise that cheapest to buy is not always cheapest to run. Yet when it comes to investment decisions, capital cost data despite being only part of the picture, can influence investment decisions like the pull of the Sirens call. Most engineers will also be familiar with troublesome assets that fail to deliver anticipated performance and soak up more time and resources than they should. Both of these situations remain unchallenged where behaviours are driven by a narrow focus on direct costs.

Life Cycle Costing, combining capital and multi year operating costs into a holistic measure of cash flow, is well known but it is often seen as a complex, difficult to apply financial analysis tool. Yet in most cases, a simple LCC model, taking under an hour to complete, will be sufficient to widen the basis of decision making leading to improved performance of both current and future assets.



Capital Costs are only part of the picture

Figure 1: Life Cycle Cost Base Case Example

This article explains how Life Cycle Cost principles can be applied in a simple but practical way to guide decision making about how to:

- Deliver the full potential of current/legacy assets;
- Make informed decisions that reduce Life Cycle Costs even when individual asset cost data are not available;
- Guide the development and implementation of working methods to deliver the full potential of assets or enhance value added from new assets prior to day one operation;
- Begin conversations about the impact future challenges to encourage innovation, engagement and a proactive improvement culture.

When to use Life Cycle Costing?

Life cycle costs analysis adds most value when used to guide choices of between future options such as upgrading current assets vs new assets. Think of it as a compass guiding the journey to optimum performance. To stick with the compass analogy, select a North West rather than a North bound direction can be made with confidence using a simple compass from a Christmas cracker. Likewise adopting a simple LCC model to compare investment options first can be all that is needed.

Naturally it is useful to have an understanding of the total cost implications of any decision but Life Cycle Cost models present an approximation of the real world. Those that approach LCC analysis seeking a precise forecast of future costs will be disappointed. The pursuit of high levels of accuracy adds complexity and may not improve the quality of decisions made. There are too many variables in the real world to forecast accurately even a year ahead, let alone 5 or more years.

Like any compass, the value it provides is zero without a clear destination in mind. For that reason, an early question to answer is "what decision do we need to make?" Then what is needed to support that decision. As mentioned above, start simple.

The conversations surrounding the creation of the model and interpretation of the outputs are as valuable as the model outputs. Creating a life cycle cost model generates conversations about cause effect mechanisms and the likely form/impact of future challenges. That in turns leads to shared insight, consensus and highlighting of gaps in knowledge. As a result, the LCC model development process generates triggers for innovation and new thinking.

For example some organisations use LCC models when tapping into potential gains from the wider availability of cheap advanced technology. Those that do this well use cross functional teams led by internal technology specialists to identify where low cost pockets of automation can deliver gains. In most cases, because the technology is so new, these internal specialists have been developed in house. Their "classrooms" are practical projects, their "curriculum" is set by near future business drivers using Life Cycle Cost Models as their compass and scorecard.

In summary, Life Cycle Costing and its supporting principles adds value to decisions involving a choice between promising options. The application examples below cover a range of suitable applications including:

- Where to target resources to improve current asset performance;
- Decisions about overhaul vs replacement of legacy assets;
- Targeting of capital investment for new assets/asset features.

Improving Current Asset Performance

Where legacy assets are troublesome, a knee jerk reaction to replace them with new ones can seem compelling. The simplest application of Life Cycle Cost analysis can help to counter this instinct by making asset life cycle cost drivers visible. The pie chart in figure 1 was developed as a base case LCC model combining capital costs with anticipated operating costs over 5 years. Operational costs for the above model in Figure 1 were collated using the data template shown in figure 2.

It is highly likely that the asset will last longer than that but 3 to 5 years was the strategic planning horizon for this organisation. That meant we could use the strategic planning assumptions and other activities expected to take place during that period. Furthermore a cost model using 5 years' operating costs, means that options considered must deliver an annual return equivalent to 20% to achieve a lower overall total cash flow. Finally, this simplification does not impact on the value of the model if it is used as the basis for comparing options.

LCC Operational Data Template

		Year				
	Reference year	**1**	**2**	**3**	**4**	**5**
Output volumes						
Raw materials						
Packaging Materials						
Services						
Electric						
Steam						
Air						
Other						
Labour						
Production						
Cleaning						
Maintenance						
Maintenance materials						
Overheads						
Rent/rates						
Heat/Light						
Total Operational Costs						

Figure 2 Life Cycle Costs Operational Data Template

In this case, the model was used to identify the cash flows that could be expected from a like for like change of asset. This provided a benchmark for comparison of options.

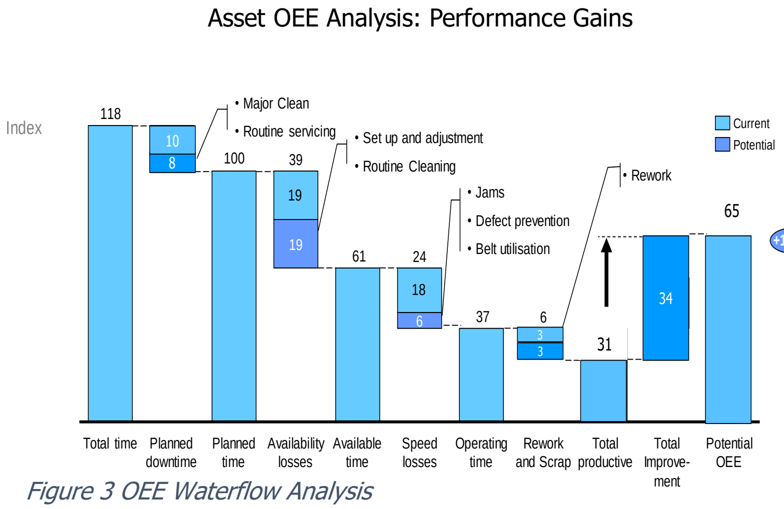


Figure 3 OEE Waterflow Analysis

Figure 3 shows an OEE analysis of the current asset to identify potential for improvement without investment in a new asset.

This analysis identified the potential to more than double current levels of effectiveness (and therefore capacity) by Improving methods to reduce set up, cleaning time and rework;

- Improving condition of critical parts of the asset to reduce breakdowns
- Minor upgrades to process control
- improve upstream processes which had a significant impact on rework and yield issues.

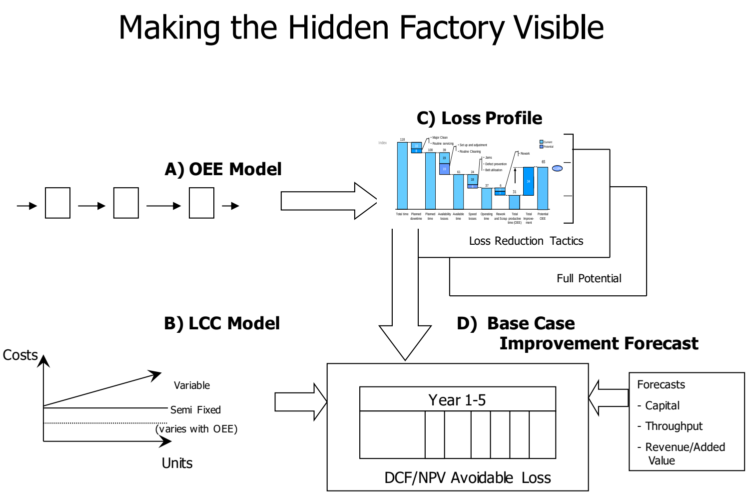


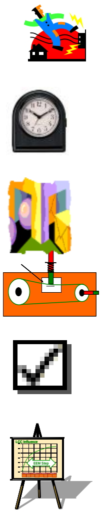
Figure 4 Combine OEE and LCC Analysis

This combination of OEE analysis with the Life Cycle Cost Data highlighted that these actions would deliver energy and material gains equivalent to around 7% of life cycle costs. The impact of increased throughput on profitability was also added to the model as a positive cash flow. The outcome was an option with similar operational gains at around 10% of the capital spend.

Reducing Life Cycle Costs

The above review included consideration of contributors to sub optimum life cycle costs due to weaknesses in Technology, Operational Methods and Product/Customer Value features. using the 6 Factors set out in the table below.

Safety and Reliability benchmarks highlighted Technology weaknesses, Operability and Maintainability highlighted complexity of operational methods and Customer Value and Life Cycle Cost benchmarks highlighted the impact of product/customer value features. The review then identified specific weaknesses that contribute to sub optimal life cycle cost performance. Following that a simple hierarchy of options for improvement were considered to assess the potential benefits of:



	Definition	3.Acceptable	5. Optimum
Safety and Environmental	Function is intrinsically safe, low risk, fail safe operation able to easily meet future statutory and environmental limits	Little non standard work Moving parts guarded, few projections Meets SHE and fire regulations Easy escape routes and good ergonomics	Fool proof/failsafe operation High level of resource recycling Uses sustainable resources
Reliability	Function is immune to deterioration requiring little no intervention to secure consistent quality	Low failure rate Low idling and minor stops Low complexity/quality defect potential Flexible to technology risks Good static and dynamic precision	High MTBI Stable machine cycle time Easy to measure Flexible to material variability
Operability	Process is easy to start up, change over and sustain "normal conditions". Rapid close down, cleaning and routine asset care task completion.	Simple set up and adjustment mechanisms Quick replace tools Simple process control Auto load and feeder to fed processing	One touch operation for height, position, number colour etc Flexible to volume risk Flexible to labour skill levels
Maintainability	Deterioration is easily measured and corrected, Routine maintenance tasks are easy to perform and carried out by internal personnel.	Easy failure detection/repair Off the shelf/common spares used Long MTBF, Short MTTR Easy to inspect and repair	Easily overhauled Self correcting/auto adjust Inbuilt problem diagnostic Predictable component life Fit and forget components
Customer Value	Process is able to meet current and likely future customer QCD features and demand variability. Provides a platform for incremental product improvement	Easy order cycle completion Maximum control of basic and performance product features Flexible to product range needs	Capacity for future demand Robust supply chain Simple logistics//forecasting needs Flexible to potential market shifts Access to high added value markets
Life Cycle Cost	Process has clearly defined cost and value drivers to support Life Cycle Cost reduction, enhance project value and maximise return on capital invested	Clarity of current capital and operational cost drivers and process added value features Potential for value engineering gain Resource economy	High level of resource recycling Flexible to financial risks (e.g. vendor) Easily scalable to 400% or to 25%

Figure 5 Determinants of Life Cycle Costs

1. Restoring equipment basic conditions;
2. Improving working methods;
3. Improving process control/reducing process complexity;
4. Low cost automation.

This generated options to:

- Improve methods by enhancing:
  - Reference planes at points of adjustment;
  - Clamping;
  - Positioning parts in fixtures;
  - Centring/alignment.
- Improve asset resilience by enhancing:
  - Access to key equipment areas;
  - Containment of dust and contamination;
  - Ease of start up, change over, run and close down;
  - Hard to clean areas.
- Reduce complexity by making it easier to:
  - Distinguish between product variants;
  - Assemble mechanisms after cleaning;
  - Replenish materials on line.

This example shows how life cycle cost analysis of existing assets before resorting to capital investment will ensure that scarce capital resources are targeted at those areas where it can add the most value.

Decisions about Overhaul Versus Asset Replacement

Another useful application of LCC modelling is support for overhaul versus asset replacement decisions. This involves creating a model of future maintenance cost such as the model below. This model uses cumulative capital and maintenance costs per 1000 run hours to predict the curve of future maintenance costs. Other versions are available.

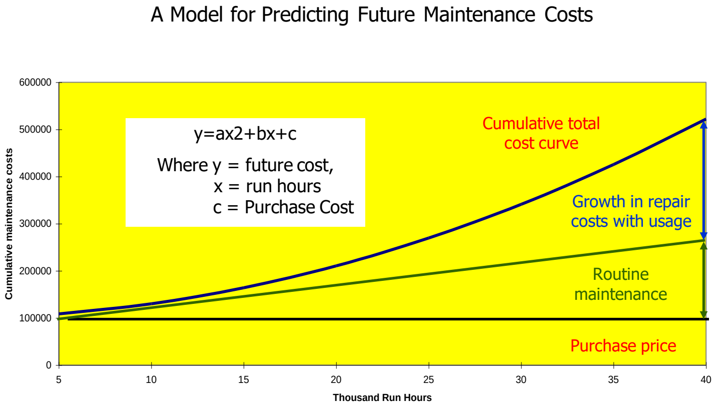


Figure 6 Maintenance Cost Forecast Model

Asset history was used to identify the cumulative cost per 1000 run hours for the asset to date. Regression analysis was then used to identify the a and b parameters of the formula $Y = ax^2+bx+c$. (see figure 6) where Y is the estimated maintenance costs at a future level of run hours (x).

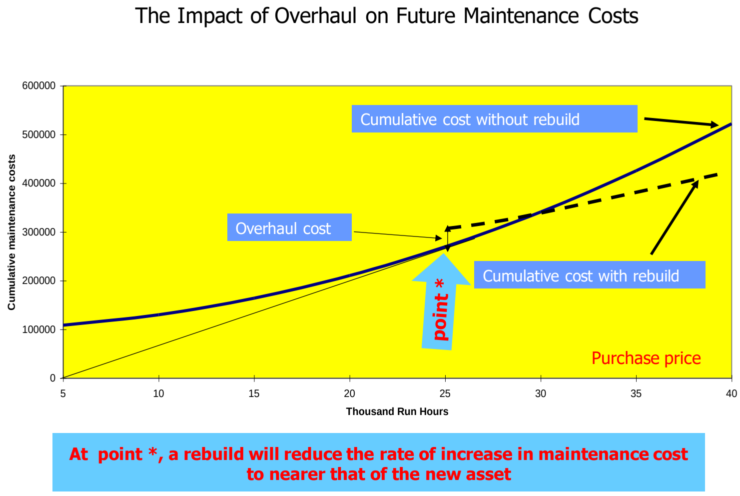


Figure 7 Impact of Overhaul on Maintenance Costs

As can be seen from figure 7, the nature of this cumulative cost curve starts is an increasingly steeper rise as the run hours increase and more costly repairs are needed to restore operations.

A tangent to the curve passing through the zero axis is the point at which cost per 1000 run hours starts to rise. (As the model includes capital and running costs, up to this point, cost per 1000 run hours will decrease). An overhaul at this point will change the shape of the maintenance spend cost curve to that of the earlier, flatter part of the curve. That provides a basis for assessing the payback from the cost of the overhaul. These costs can then be used within a LCC option and compared to the base case to identify the gains from a new asset.

Targeting Investment for New Assets/Features

The delivery of capital equipment projects with lowest life cycle costs is one of the goals of the Early Equipment Management (EEM). This approach is sometimes referred to as Design to Life Cycle costs or DTLCC. The scope of this approach starts with investment decision making, includes design and delivery processes and optimisation of asset performance to achieve maximum value added over the life of the asset (See table 1 below).

As mentioned earlier, in most cases, a simple LCC model will be sufficient to support a comparison of options under consideration.

In some cases, it may be necessary to build n this an create a more detailed LCC analysis for example:

- Support a fund application;
- Review decision sensitivity to best case/worst case business scenarios;
- Gain a greater insight into risks/opportunities.

The table below sets out Life Cycle Cost Model application areas over the life of a capital project.

	EEM Step	Goal	LCC Application
1	Concept	Define the project scope	To compare scenarios and assess the likely benefits of the preferred option
2	High Level Design	Clarify the delivery approach, obtain funding and select the right partner	To compare delivery approaches to the preferred option and firm up on the EEM targets
3	Vendor selection and Detailed Design	Tease out latent design weaknesses, problem prevention, enhance project value	To analyse the main contributors to LCC, improve project, design and operational efficiencies
4	Pre Fab Procurement	Develop site readiness plans and assure the quality of new asset manufacture	Add detail to LCC model and gain insight into how to manage LCC drivers
5/6	Installation/ Commissioning	Delivery of flawless operation	Refine operating methods, support problem solving and focussed improvement to minimise start up period and performance losses.
7	Stabilisation	Stabilise new asset performance and identify asset optimisation road map	To confirm achievement of LCC targets/benefits and support development of optimisation targets

Table 1 EEM Steps and LCC Applications

Life Cycle Cost Model Development

Life Cycle Costs models are of most value when they are developed on a cross functional basis using parameters aligned with assumptions and planning criteria used by other business systems such as:

- Site business plans;
- Capacity planning models;
- Financial rules of thumb.

As mentioned above, the process of developing this across functional boundaries improves insight, consensus and engagement with the outputs of the analysis.

Figure 8 sets out the steps and cross functional roles involved in developing and using the Life Cycle Cost analysis.

Steps 1-4: Define and validate the base case LCC model
Steps 4-6 Cover development of options for review and evaluation to identify a preferred approach
Step 6: Confirm/refine preferred approach based on strategic risk assessments/scenario plans.
Step 7: Update LCC model as required

Life Cycle Cost Analysis Steps

1	Base case LCC model design	Steering Group	Fin	Project Manager	Users
2	Populate model	Users	Fin	Mgmnt team	Project Manager
3	Approve/validate model	Steering Group	Fin	Mgmnt team	User
4	Generate options and evaluate	Users	Project Manager	Mgmnt team	Fin
5	Review and confirm analysis	Project Manager	Fin	Mgmnt team	User
6	Assess impact of strategic change on LCC model	Project Manager	Fin	Mgmnt team	User
7	Revisit/revise/update LCC model as required	Users	Project Manager	Fin	SM

Figure 8 Cross Functional LCC Model Application

Case Study Example

Below is an example of how LCC analysis was used to evaluate 2 competing options by comparing them against a base case model. In this example a base case model had already been developed containing the Life Cycle Cost flows used to support the justification of the capital spend. The review was part of the Early Equipment Management process to assure delivery of those targets by seeking to further reduce LCC and enhance project added value. As part of that activity the 2 options under consideration here had been previously shortlisted from a long list of 7 options.

The first step was to identify the base case parameters to be adjusted to create the option LCC estimate for each option. This is set out in figure 9 below.

Parameter	LCC analysis approach	Action needed	Parameter	Option 2	Option 3
Space needed	Building cost per m2	Compare footprint size adjust capital cost	Capital cost		+£440k
Energy	Energy cost per case	Estimate % energy saving vs benchmark	Energy	-15%	-15%

Parameter	LCC analysis approach	Action needed	Parameter	Option 2	Option 3
Waste	Frequency of jams times mat waste per jam plus recovery time	Use same standard for both options based on line 3 benchmark	Material Waste	.6%	.3%
Labour	Labour cost per case	Estimate % difference in team size from benchmark	Labour cost		+50kpa
Change over	Increased line availability impact on capacity	Team labour cost per run hour by time saving	Labour cost		+£1.8k pa
Capital Cost	Most recent cost	£1m differential	Capital cost		+£270

Figure 9 Defining Life Cycle Cost Comparison Parameters

As shown in figure 10, option 3 resulted in a LCC of £108k lower than base case model cost. Option 2 resulted in a LCC of £537k higher than the base case.

Case Study LCC Option Evaluation

Base Case	Capex £k	Year						
		2016	2017	2018	2019	2020	Total	%
Capital costs	8200.00	0.00	0.00	0.00	0.00	0.00	8200.00	18.9%
Operating costs	0.00	7018.55	7018.55	7018.22	7018.55	7018.55	35092.42	81.1%
Total Annual Cashflow	8200.00	7018.55	7018.55	7018.22	7018.55	7018.55	43292.4212	
Cumulative Cashflow	8200.00	15218.55	22237.10	29255.32	36273.87	43292.42		

LCC Base Case +£537k

Option 2	Capex £k	Year						
		2016	2017	2018	2019	2020	Total	%
Capital costs	8200.00						8200.00	18.7%
Operating costs		7125.94	7125.94	7125.61	7125.94	7125.94	35629.35	81.3%
Total Annual Cashflow	8200.00	7125.94	7125.94	7125.61	7125.94	7125.94	43829.3525	
Cumulative Cashflow	8200.00	15325.94	22451.87	29577.48	36703.42	43829.35		

LCC Base Case -£108k

Option 3	Capex £k	Year						
		2016	2017	2018	2019	2020	Total	%
Capital costs	7930.00						7930.00	18.4%
Operating costs		7050.96	7050.96	7050.63	7050.96	7050.96	35254.47	81.6%
Total Annual Cashflow	7930.00	7050.96	7050.96	7050.63	7050.96	7050.96	43184.4702	
Cumulative Cashflow	7930.00	14980.96	22031.92	29082.55	36133.51	43184.47		

	Base case £k	Option 3	Option 2	Option 3-2
Capital costs	£ 8,200.00	£ 7,930.00	£ 8,200.00	-£ 270.00
Material	£ 27,008.15	£27,170.20	£ 27,089.18	£ 81.02
Energy	£ 2,830.63	£ 2,830.63	£ 2,830.63	£ -
Production	£ 4,045.34	£ 4,045.34	£ 4,501.25	-£ 455.91
Maintenance materials	£ 1,208.30	£ 1,208.30	£ 1,208.30	£ -
	£ 43,292.42	£43,184.47	£ 43,829.35	
			Option 3	-£ 644.88

Figure 10 LCC Option Evaluation Results

As both options were compared using a base case model the difference between the two options of £645k was defensible even though the base case model was relatively simple. Had the difference been closer a more detailed analysis would have been carried out but in this case, that was not necessary.

In this case study, the base case Life Cycle Cost model had already been created which meant that the above comparison took less than 30 minutes to complete.

Conclusions

Life Cycle Cost analysis provides an insight into total operational cash flows to improve decisions about where to target those scarce resources of skilled labour and investment capital to improve future business performance. The process of creating and using that information moves the conversation on from discussions about dealing with the consequences of failures to a topic where engineers add the most value. The future. What's not to like?

Dennis McCarthy is a Director with DAK Consulting who specialise in developing companywide capabilities to deliver year on year improvement in performance. www.dakconsulting.co.uk
Dennis.mccarthy@dakconsulting.co.uk
DAK also offer short training courses to develop improvement leader capabilities for maintenance, manufacturing and support functions. www.dakacademy.com