THE IMPACT & INTEGRATION OF LIFE CYCLE COSTING WITHIN PRODUCT DEVELOPMENT COURSES.

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ABSTRACT
The main objective of Life Cycle Costing (LCC) is to quantify the total cost of ownership of a product throughout its full life cycle, which includes: research, design, development, construction, operation, maintenance and disposal, [1].
Research has shown [2,3] that LCC becomes more crucial when technology changes rapidly and the Product Life Cycle (PLC) becomes shorter.
This has become more evident over many years and is set to continue into the foreseeable future.
With so much emphasis placed upon LCC, and the impending legislation with respect to End-of-Life considerations, it has become necessary to not only build LCC into Higher Education curricula, but also to ensure that the teaching of the subject is fulfilled in such a way as to treat LCC as an integral element within the PLC, and not taught as a separate to Business and Economics students.
This paper reflects upon work carried out at Northumbria University, England which seeks to develop a generic approach to Product Development, the identification of key aspects of LCC which could be readily absorbed within the existing curricula.
The initial studies were carried-out through the development of an Electronic Security System and confined itself to decision analysis within the design activity.

1 LCC BACKGROUND
In many industries, there is a growing understanding of the importance of the right decision being made at the earliest possible time within the PDC, specifically at the concept and development phases. These phases represent the smallest amount of overall product cost expenditure, but the effect of the right decisions made at these stages is highly leveraged, because they have the greatest impact on the overall life cycle costs, refer to table 1.

Table 1 Leveraged Effect of Design Phases in the Electronics Industry

Life Cycle Phase	Incurred % of Total Cost	Committed % of Total Cost
Conception	3-5	40-60
Design	5-8	60-80
Testing	8-10	80-90
Process Planning	10-15	90-95
Production	15-100	95-100

LCC is a powerful tool that can be applied at any stage of the PDC. It can be used to provide information to make decisions regarding design, manufacture, installation, maintenance, operation and disposal of an asset.
In this sense, the objective of LCC is to choose the most cost-effective approach from a series of alternatives so the lowest long-term cost of ownership is achieved, [4].
LCC techniques involve time calculations in order to analyse different alternatives over the life of the asset.
The calculation of LCC can be carried out as follows:-

$$LCC = \sum_{t=0-N} \frac{Ct}{(1+d)^t}$$

Ct = Sum of all relevant costs, less any positive cash flows occurring in time period t.
N = Number of time periods in the study period.
d = Discount rate for adjusting cash flows to present value.

To enable the optimization of the cost of owning or using physical assets implies the realisation of three groups of costs, first, the capital costs of creating the asset, second, the costs of operating and maintaining the asset during its operational life, and third, the costs of asset disposal, [5].
A company that is designing and manufacturing a product for sale will incur the following Fixed Costs:

- Research & development
- Defining specifications
- Design
- Product approval
- Manufacture
- Quality control & testing of prototypes

These will be added to Variable Direct Costs of:

- Material & components
- Manufacturing (labour content)
- Disposal or end-of-life

and Variable Indirect Costs of:

- Quality Control & Testing
- Maintenance

These three aspects of cost assessment within the design and manufacturing company essentially cover the requirements of costs of owning the physical asset since the costs of operating and maintaining should be embedded within the Product Evaluation phase of all design and manufacture companies.
It is this model of Product development and LCC which forms the basis for the research at Northumbria University, or more specifically, the decision making process and the subsequent embedding of LCC content within the Product Development of degree programmes.

2 PRODUCT DEVELOPMENT AT NORTHUMBRIA UNIVERSITY

At Northumbria University we are developing a generic module with respect to Product Development across a range of programmes in terms of lecture content, and practical, hands-on activities.

This approach has been agreed upon for efficiency reasons due to declining numbers of students applying to Engineering based programmes over the last number of years. Quantitatively, we have seen an approximate 30% reduction over the last 15 years registering on an increased portfolio of undergraduate programmes.

The programmes currently participating in this module are:-

- Electrical & Electronic Engineering
- Communication Engineering
- Electronic Design Technology
- Computer & Network Technology
- Product Design Technology

It is hoped that future participation will include:-

- Mechanical Engineering
- Manufacturing Systems Engineering
- Mechanical Design Technology

to allow for the broadening of specialized knowledge required for more effective product development.

One of the many key considerations in developing this integrative approach to Product Development is the student design entry. The module sits in the second academic year of three academic year programmes. Each of the programmes not only contain differing content in year one modules, but also we accept direct entry to the second academic year making the syllabus lecture content for product development difficult.

To allow the introduction of LCC within the student product development process necessitated the initial research & identification of the key aspects of LCC which would be readily absorbed within the curricula. Subsequently, determination of the required lectures to allow this absorption within the existing curricula was required.

3 LCC IN PRODUCT DEVELOPMENT

The structure and content of LCC is all encompassing with respect to the PLC, it was because of this that it was decided to analyse the content and select an element which would potentially give maximum benefit within the Product Development courses at Northumbria.

Referring to table 1 it is apparent that being able to influence the decision making process within the Concept and Design phase could generate the most cost savings with respect to the project, since up to 80% of cost is committed at this stage.

It was therefore agreed to pursue the introduction of LCC within this area of the students product development work ie where there are several possible options to satisfy the Product Design Specification functional content.

For the purpose of student efficiency this LCC decision optimizing tool must be easy to use and software based.

The satisfy our requirements the software needed to be able to:-

- Allow the comparison of various alternatives
- Provide sensitivity analysis
- Net Present Value computations
- Cost Breakdown Structure Trees
- Allows total lifetime costing
- Allows the use of design, production, warranty, repair & disposal costs.
- Provides for automatic link to Reliability 7 Maintainability information.

To provide a vehicle for the determination and suitability of a proposed piece of software within our course we considered the practical case of a present project, that of designing an Electronic Security System.
The system comprised the following elements:-

- Control Panel
- Keypad
- Communication Module
- Remote Zone PCB
- RS485/232 interface
- Power Supply

Consideration was given to three options for distinct sectors of the market place, namely:-

- Product A, good quality in the mid price range
- Product B, low quality in the low price entry level.
- Product C, very good quality in top of the range price category.

Although there are many different software packages in the market place, the Relex System was chosen for reasons of economy and the modular fashion with which the Suite of softwares may be purchased. The total suite consists of:-

- Reliability Prediction Engine
- Reliability Block Diagram
- Fault Tree Analysis
- Failure Modes & Effects Analysis
- Maintainability
- Life Cycle Costing

The results of using this package, solely to assist in the decision making process, was as follows:-

1. Cost Evolution:- This presents the Net Present Value cost of the options over the Product Life cycle. In this case Product A showed the least cost.

2. Cash Flow Evolution:- This presents the Net Present Value cash flow over the Product Life Cycle. This showed Product A having a larger resultant profit at end of life cycle.

In this case it was seen that if the company developed Product A or B the payback period would be approximately 3.5 years. If Product C were chosen the payback period would be approximately 4 months.
At this stage a decision may be taken to adopt Product A as it shows greater benefits via the Cash Flow Evolution diagram. This resultant decision must be weighted against the long term benefits to the company of developing the Product C whose very high quality may establish a greater market leverage for future products.
For the purposes of this exercise Product A was chosen to be developed as the best cost effective solution. This enabled a Sensitivity analysis to be carried out in order to determine the Cost Drivers of the product.
One of the key features of Relex LCC is not only the ability to allow informed decisions regarding choice of design options, but also the ability to determine how robust a particular option is, and how sensitive the overall cost is to certain variables.
When performing a sensitivity analysis, the operator specifies a variable to modify and a percentage range over which to modify the variable.
Within this case study it was decided to concentrate upon production related variables as this is where, logically, most of the costs would be expended. From this variables of functions of Cost of Production, Yield and Overhead were selected.

Table 2. Sensitivity Expressed as GBP(NPV)

Variables	**80%**	**90%**	**100%**	**110%**	**120%**
Overhead	170	173	175	177	180
Production Yield	165	170	175	183	192
Production Cost	163	168	175	181	182

Table 2 shows that functions of Yield and Cost of Production are very much more cost sensitive than the function of Overheads.
Actions which may arise from such a tabular result might include:-

- Improving Productivity through production aids, factory layout, design for manufacture, assembly & test.
- Improving Yield through analysis of incoming materials, material & component selection & application criteria in design, process capability, failure modes & effects analysis.

4 CONCLUSIONS

The general aim of identifying LCC and its constituent parts for use within a Higher Education have been shown through the vehicle of a real product development ie an Electronic Security System.
The emphasis was placed upon the decision making process and selection of an appropriate option within design, along with an analysis of the chosen products cost sensitivity.
The result of this exercise showed the interdependence of decisions made regarding to cost and other elements within the Product Life Cycle. This supported the main philosophy of the Product Development courses delivered at Northumbria University.

The delivery of LCC concepts within Northumbria's courses will commence within the next academic year of 2004/05, the format of which will be an extension of content within the existing approach of lectures and practical hands-on team work.

REFERENCES

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