Reliability-based Life Cycle Cost Calculation
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About Myself

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- Part of ABB Corporate Research Life Cycle Science Group

My Subjects of Expertise:
- Software Engineering
- (Meta-)Modeling
- Reliability Engineering
- Life Cycle Cost Calculation
Agenda

- Life Cycle Cost Calculation
  - General Theory
  - ABB‘s Generic Model
- The Motors & Generators Domain
- Tool Example
- Conclusions
Life Cycle Cost Calculation
**Life Cycle Cost**

- **Life Cycle Cost** is the owner's total cost accumulated during the life cycle of a particular product instance.
- **Life Cycle Cost Calculation**: Formalized approaches for the assessment of LCC.
Some Motivations for Doing LCC Calculations

- Pick the Inexpensive Solutions Instead of Cheap Products
- Future Budget Planning
- Identify Targets for Product and System Improvement
What Life Cycle Cost Calculation is not!

- A precise prediction of future cash flows that actual results can be benchmarked against
- The basis for a long term plan that will not be changed over the whole life cycle
- A universally applicable LCC model is difficult to achieve and probably even more difficult to use
Application Domains

- Bridges / Roads
- Buildings
- Carpeting [KR04]
- Mechanical And Plant Engineering [DS06]
- Motors and Generators
- .....
Some LCC-related Standards

- DIN EN 60300-3-3 Dependability management – Part 3-3: Application Guide – Life Cycle Costing
- VDI 2884 – Purchase, operating, and maintenance of production equipment using Life Cycle Costing (LCC)
- VDMA 34160:2006-06 Forecasting model for lifecycle costs of machines and plants.
Common Properties of the Domains (I)

- Different Cost Factors
- Different System Elements
- Different Life Cycle Phases

Figure taken from [DI05]
Common Properties of the Domains (II)

- Different Cost Factors
- Different System Elements
- Different Life Cycle Phases
- Follow-Up Cost Crucial
- Discounted Cash Flows
- Long Term Investments
Different Cost Drivers
This is the reason why we need different models for the different domains!

Different Cost Factors

Different System Elements

Follow-Up Cost Crucial

Different Life Cycle Phases

Uncertainty

Discounted Cash Flows

Long Term Investments

Universal Model Challenges
Universal Part of an LCC Model (I) Model Principle

PC 2007
PC 2010
Windows 2007

PC
PC
PC
PC
PC
PC

OS
OS
OS
OS
OS
OS

One year

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Universal Part of an LCC Model (II)
Monte Carlo Based Cost Calculation
The Motors & Generators Domain
Domain Properties

- Expensive, **long-lived equipment** (as opposed to merely long-lived system)
- **Repair of subcomponents** (as opposed to complete equipment)
- Elaborate **preventive maintenance plans** which impact the life expectancy of components
- Machines consume large amounts of **energy**
- Some **failures can be compensated** by increasing load on other equipment
- **Failure rate** depends on load, start-ups and similar factors more than on physical age
Cost Drivers

- Acquisition
- Energy Cost
- Motors & Generators
- Repairs
- Preventive Maintenance
Key Challenges

Challenges:

- Include all **cost drivers**
- **Subcomponents as first-class citizens** (individual ageing, repairs etc. on component and not equipment level)
- Model **generic preventive maintenance**
- Include load and other **failure-relevant effects**

Constraints:

- The more realistic the model, the better **training** the user requires
- Model complexity increases **chance of errors** and time for data collection and calculation
- Many **mathematical models describing repair effects** are not verified in the real world
Extensions to ABB’s LCC Model (Stage 1)

- Preventive Maintenance Tasks
- Spare Parts Modeling
- Energy Cost

Currently Internal Study Only – Not Available as Product or Service!
M&G Model – Stage 1
Example: Preventive Maintenance Measures

- <<Type>> Hardware (Sub)Component
- <<Type>> Maintenance Task
- Interval Manhours
- Downtime
- Parts Used
- Consequence

<table>
<thead>
<tr>
<th>Task performed</th>
<th>Task not performed</th>
</tr>
</thead>
<tbody>
<tr>
<td>X1 Stay</td>
<td>X2 Stay</td>
</tr>
</tbody>
</table>

- Total Man Hours
- All Parts Used
- Total Time
- Criticality

- Maintenance Personnel Cost
- Maintenance Material Cost (Spare Parts)
- Downtime Cost During Maintenance
Example for Preventive Maintenance Cost

**Prev. Maint. Task 1**
Every 5 months
2 people for 2 hours (=4 manhours)
Repeats

**Prev. Maint. Task 2**
In month 20
3 people for 2 hours (=6 manhours)
Does not repeat

**Year 2:**
2x Task 1
1x Task 2
Manhour = 100 Euro
Downtime = 10’000 Euro

14 Manhours = 1’400 Euro
6 Hours Downtime = 60’000 Euro
Material Cost = 3’000 Euro

2x Spare Part 1 (1’000 Euro)
1x Spare Part 1 (1’000 Euro)

Effects of non-maintenance come into play with decreased MTBFs.
LCC Tool
Main Screen
LCC Tool
Adding Equipment

[Image of LCC Tool interface]
LCC Tool
New Item in Life Cycle
Note: Data from different example
Conclusions
Conclusions

- There are different motivations to look at LCC
- LCC depends heavily on the domain
- To access a domain, key cost drivers must be identified and modeled
- ABB has a tool that is gradually expanded to work on the different domains relevant for our business

Any Questions?
References


[VD05] Verein Deutscher Ingenieure: VDI 2884 – Purchase, operating, and maintenance of production equipment using Life Cycle Costing (LCC)