The Impacts of Design Change on Reliability, Maintainability, and Life Cycle Cost
Case study: Combat Vehicle 90 - Rubber versus steel tracks?

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Presentation outline

- Bottom-up engineering approach to Cost Analysis – An important complement to the Parametric Approach

- Modeling and Simulation of Systems’ Operation and Logistics Support – A great way to generate data for cost analysis (In addition to providing invaluable decision support for Life Cycle Management)

- Case study example – LCC evaluation of a CV90 design change

- Conclusions
Consultancy in systems and logistics engineering.

The Opus Suite: software for logistics support optimization and life cycle system management used by defense authorities and industry leaders worldwide.

Founded in 1970, an independent, partner owned company with offices in:
- Washington DC, Florida, and Colorado
- Stockholm, Sweden and Weymouth, UK
Customers

- Australian DMO
- Belgian Army
- Brazilian Air Force
- Danish DoD (DALO)
- Dutch DoD
- French Air Force
- Italian Navy
- NATO Heli PO (NAHEMA)
- Norwegian MoD (FLO)
- OCCAR
- Singapore DoD (DSTA)
- South Korean Army
- South Korean Navy
- Spanish Air Force
- Swedish MoD (FMV)
- Thai Air Force
- Turkish Air Force
- UK MoD
- US Air Force
- US Navy (NAVSEA)
- US Navy (NAVAIR)

Agusta Westland
- Airbus Defense and Space
- Airbus Helicopters
- Alenia Aermacchi
- BAE Systems
- Boeing
- CAE
- Dassault Aviation
- FFG
- Finmeccanica
- GKN Aerospace
- Hanwha
- Israel Aerospace Industries
- Kongsberg
- Krauss-Maffei Wegmann
- LIG Nex1
- Lockheed Martin
- Marshall Aerospace
- MBDA
- Nexter
- Northrop Grumman
- QinetiQ
- Raytheon
- Rheinmetall Landsystem
- Rockwell Collins
- Samsung Thales
- SAS Selex
- Saab AB
- ST Electronics
- Textron
- Thales Defence
- Turbomeca
- Turkish Aerospace Industries
- Alstom
- Bombardier Transportation
- Heli-One / CHC
- Maersk Drilling
- Nokia
- ST Aerospace Solutions
- SuperJet International
- Telstra
Reducing Total Cost of Ownership

Decision:

Decisions without LCC focus often lead to cost increases

Budget (LCC):

100%

50%

Committed part of TOC

Possibility to influence

Accumulated cost

All major decisions should consider TOC/LCC!
Approaches to Cost Estimation and Analysis (NATO RTO Tech report TR-SAS-076)

- **Analogy Approach**
  Top-down cost estimation that forecasts the cost of a new system based on the historical cost of one or several similar systems. Selected “complexity factors” are often used to adjust the estimate.

- **Parametric Approach**
  Top-down cost estimation where linear regression models are typically used to forecast the cost of a new system based on a multitude of selected cost driving variables.

- **Engineering Approach**
  Bottom-up cost estimation starting from a low level of definable cost elements within the cost breakdown structure and building up to estimate the total cost of a new system.
Comments on the Engineering Approach (TR-SAS-076)

- “It is the most detailed of all the techniques and the most costly to implement.”
- However, “it provided some key advantages”:
  - [It] is highlighting the critical aspects in the design and its logistical organization, which makes it a tool for project management and systems engineering.
  - It provides a structured way of weighing significant technical and cost inputs.
  - It shows the economical consequences of the technical system properties over time, which provides the means of evaluating the cost implication of a proposed system solution.
  - [It] allows the user to determine the cost efficiency of the system.
  - Cost drivers can be identified and more detailed analysis on costs can be started.

- “The engineering method is trying to minimize the need of input data taking into consideration only those costs and related parameters which influence the decision making process.”
- Look at the engineering method as an on-going enterprise during the system life time, i.e., “from cradle to grave”. Applied properly and consistently, the method not only implicitly leads to improvement of the system efficiency, but also gives the system operator after a period of time, access to a database similar to VAMOSC which will substantially improve the future Life Cycle Cost estimations.
Life Cycle Management
Decisions that call for thorough analyses:

**MAIN OBJECTIVE:** Ensure that operational requirements are fulfilled at the lowest cost throughout the system’s life cycle.

- **What types of systems do we need?**
  - Requirements definition

- **Which technical system (vendor) should we choose?**
  - LCC/TOC-based procurement

- **Which logistic concept should be implemented?**
  - Optimized logistics support

- **Status and possible improvements of the system?**
  - Monitoring + cost effective improvements
Key Decisions Requiring Analysis

- What requirements should be put on a new system?
- What is our budget?
- Which system should we purchase?
- What kind of supply solution is optimal?
- What investments in logistic support, spares, and other resources do I need to make, and where should they be located?
- Can we handle the planned operations with the current support solution?
- What improvements are most cost-effective to enhance my operations?
- How much do we have to lower the failure rate of a certain system or component to reach target availability?
- When the operational profile or the environment changes, how does that impact my solution?
- When should I replace the existing fleet of systems?
Parameters that affect costs

**DECISION**
- Choice of one component
  - Price
  - Reliability
    - Failure / Removal rate
  - Maintainability
    - Repair / Resupply TAT
  - Support Solution
    - Lead times
    - Personnels
    - Tools
    - Transports

**COSTS**
- Initial spares cost
- Spares replenishment
- Downtime costs
- Personnel cost
- Tool costs
- Reorder costs
- Transportation costs

Complex and interdependent!
OPTIMAL BALANCE BETWEEN OPERATIONAL PERFORMANCE AND OVERALL COST
Case Study:
LCC Analysis of Track Alternatives
Combat Vehicle 90
Combat Vehicle 90

- Producer: BAE Systems
- Users: Sweden, Norway, Finland, Denmark, Switzerland, and the Netherlands
- Deployed in Afghanistan and Liberia
- More than 1,000 vehicles produced
- Weighs up to 35 tons
Track alternatives project background

- CV90 originally comes with steel tracks
- In the Middle East operations - problems with crew fatigue due to vibrations
- Rapid development of rubber tracks for heavy vehicles
- Several existing and potential CV90 customers have shown interest to use CV90 with rubber tracks
## Rubber Tracks Investment - Effects on LCC?

<table>
<thead>
<tr>
<th>Steel tracks</th>
<th>Rubber tracks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well proven</td>
<td>Reduced vibrations</td>
</tr>
<tr>
<td>Longer lifespan</td>
<td>Reduced noise</td>
</tr>
<tr>
<td>Repairable</td>
<td>Increased mobility</td>
</tr>
<tr>
<td>Cheaper</td>
<td>Reduced weight</td>
</tr>
</tbody>
</table>

### For old customers with steel tracks

<table>
<thead>
<tr>
<th>Existing maintenance organisation (Acquisition cost)</th>
<th>New maintenance organization (Acquisition cost)</th>
</tr>
</thead>
</table>

### Reduced vibrations means

- Longer lifespan for system and components
- Crew fatigue decreases
- Less ammunition discarded due to vibrations
- Less damage on roads
Project Approach

- BAE Systems and Systecon worked together on the project.
- Three weight classes were analyzed:
  - 25, 30, and 35 tons (6 types of CV90)
  - Opus Suite was used for the analysis.
- Data and results are confidential - this presentation focus on the method.
Organization and Operational Profile

Training
Static scenario repeated over 15 years

Annual average / vehicle
Operating time, hours. 1418  390
Operating distance, km 3818  1050

Deployment /year  Training /year

Maintenance line 1 (Repair & Stock)
Unit 20 vehicles
2 hrs

Maintenance line 1 (Repair & Stock)
Unit 20 vehicles
2 hrs

Maintenance line 1 (Repair & Stock)
Unit 20 vehicles
2 hrs

Maintenance line 1 (Repair & Stock)
Unit 20 vehicles
2 hrs

Maintenance line 1 (Repair & Stock)
Unit 10 vehicles
2 hrs

Maintenance line 1 (Repair & Stock)
Unit 10 vehicles
2 hrs

Mission
Dynamic scenario
Year 1-2 on mission
Year 3 off mission
Year 4-6 on mission
Year 7-8 off mission
Year 9-11 on mission
Year 12 off mission
Year 13-15 on mission
Modelling and Analyses workflow

0. Scenario modelling
- LSAR data from BAE
  - Bill of Material
  - MTBF
  - Item Price
- Scenario Data
  - Support organization
  - System deployment
  - System Utilization
  - Resources

1A. Optimization (calibration)
- Spares investment
- Spares consumption
- Repair volumes

1B. Simulation (validation)
- Resource utilization
- Dynamic effects

2. Cost analysis
- Additional cost parameters
  - Track throwing cost
  - Modification costs
  - Ammunition discard cost
  - Hull cracks cost

Different operational profiles

Relevant and unbiased TOC
- comparison of alternatives
- Cost breakdown analysis
- Cost driver identification
- Sensitivity analysis
Cost Breakdown Example

- **CAM**, Track Modification Acquisition Cost
- **CII**, Item Investments
- **CIMD**, Track Maintenance Documentation Modification Cost
- **CIME**, Track Maintenance Equipment Modification Cost
- **CIMT**, Track Maintenance Training Modification Cost
- **CNCP**, Partially Repairable Item Corrective Maintenance Costs
- **CNCS**, System Corrective Maintenance Costs
- **CND**, Spares Consumption Costs
- **CNHC**, Hull Cracks Corrective Maintenance Cost
- **CNO**, Spares Reordering Costs
- **CNTT**, Track Throwing Corrective Maintenance Cost
- **COAD**, Ammunition Discard Cost
- **COFC**, Fuel Consumption Cost
- **COST**, System Transportation Cost
Conclusions CV90 LCC-project

- The approach was successful
- The member countries could base their decision regarding rubber tracks on an objective comparison of how System Life Cycle Cost was affected by the differences in design, reliability and maintainability for the two alternatives.
- We could easily identify the cost drivers to determine which parameters to focus on.
- We could determine how much lower failure rates the systems and components must be in the rubber tracked vehicles to get pay back. This “backwards calculation” is very effective when you do not have all data!
- The project result views the differences and similarities in LCC for the different track systems.
Conclusions - General

- Successful Life Cycle Management of technical systems requires an ability to understand and influence the parameters that have impacts on operational performance and Life Cycle Cost.
- Engineering “bottom-up” cost analysis can provide powerful decision support for cost effective systems engineering and life cycle management.
- Modeling and Simulation can be used to provide objective leveled-off data for bottom-up cost analysis.
- With a baseline model in place, it is easy to perform “what if” analyses and to adapt to new operational scenarios, changes in the logistic prerequisites, etc.
IN SEARCH FOR THE OPTIMUM

THANK YOU FOR LISTENING!