DEVELOPMENT OF A DESIGN-TO-COST METHOD USING A SENSITIVITY ALGORITHM APPLIED TO A SAMPLE COST MODEL

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Agenda

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Problem Statement

Lack of adequate cost analysis tools early in the design life cycle of a system contributes to non-optimal system design choices both in performance and cost. The goal is to develop algorithms for an automated tool/approach utilizing cost element sensitivity to enable a system designer the ability to understand the relative cost impacts of various decision/choices which affect system design early in the design cycle for an airborne based RADAR system for military aerospace applications.
Problem - Illustrated

Unidirectional Process which lacks Feedback to Optimize a Solution
An Illustration From the Perspective of a System Designer
Complex System

Start with a System design
Complex System

There is:
• A System
• Subsystem Blocks
• Components
Complex System

Focus on Components
Load System into cost model tool.

Calculate System Cost

Complex System
Complex System

Goal: Positively Impact System Cost

$$$

$\$\$\$$
Determine cost if there is improvements on this ONE Component

Calculate System Cost

$$$

Complex System
Complex System

Try again.
Determine cost if there is improvements on this ONE Component

Calculate System Cost

$$$

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Vision Of A Solution

The “WHAT IF” scenario
What if it was possible to understand the Components in terms of cost sensitivity to overall System cost?
What if it was possible to understand the Components in terms of cost sensitivity to overall System cost?
Select a few Components, using knowledge of the System, for reasonable improvement goals.
Complex System

Determine impact of simultaneous improvements on these Components

Calculate Cost Impact
Determine impact of simultaneous improvements on these Components

Complex System

Calculated Cost Impact

21%!!
In order to realize a potential component improvement, there needs to be some amount of investment of resources. If there is a potential improvement of $1.78M in system cost, any investment up to that value would yield a profit.

So, the cost algorithm yields an upper limit for a Return On Investment.

<table>
<thead>
<tr>
<th>Baseline System Cost</th>
<th>$8,464,002.22</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Improved System Cost</td>
<td>$6,682,902.18</td>
</tr>
<tr>
<td>Savings</td>
<td>$1,781,100.04</td>
</tr>
<tr>
<td>% Improvement</td>
<td>21%</td>
</tr>
</tbody>
</table>
What Industry Needs

Process for an optimized solution
What Industry Needs

Current State Of The Art
Given a system design, a COTS cost package can calculate cost.

Process for an optimized solution
What Industry Needs

Current State Of The Art

Given a system design, a COTS cost package can calculate cost.

This is possible!

Process for an optimized solution

This is a bonus!
Cost Algorithm Details
Early Excel based cost model work - 2014

Solving the BOE conundrum - 2015

Early Cost Sensitivity Discoveries - 2014

Dynamic BOE Linkages - 2015

Standardized Block Diagrams - 2018

Path to the Cost Sensitivity Algorithm has been developing over many years
Developing the Cost Algorithm
Sample Cost Model
Sample Cost Model was selected from library.

Impactful Parameters were identified:

It is necessary to determine which Parameters could be considered Minor Parameters vs. Impactful Parameters. Primarily this was accomplished by adjusting the Parameters and observing the impact to overall system cost. In addition, some amount of Engineering judgement was used.
When a Parameter is dithered from its baseline value, it has the effect of driving the overall System cost away from the baseline. By taking the absolute value of both delta costs, the deltas are essentially folded over in the positive direction and can be compared.
In this example, it can be seen that dithering the number of PCBs in the Receiver had roughly twice the impact to the overall cost as that in the RF Module. Clearly the Receiver is more SENSITIVE to this parameter.

This became the “Ah-Ha” moment which demonstrated different cost sensitivities for different Components with the same Parameter.

<table>
<thead>
<tr>
<th>Hardware</th>
<th>Parameter</th>
<th>Parameter Value</th>
<th>Dither amount</th>
<th>Dither &quot;Up&quot; Parameter Value</th>
<th>Dither &quot;Down&quot; Parameter Value</th>
<th>Calculated System Cost Baseline Cost</th>
<th>Dither &quot;up&quot; cost</th>
<th>Dither &quot;Down&quot; cost</th>
<th>delta &quot;up&quot; cost</th>
<th>delta &quot;down&quot; cost</th>
<th>delta &quot;mid&quot; cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Receiver</td>
<td>Total CCAs</td>
<td>2</td>
<td>20%</td>
<td>2.4</td>
<td>1.6</td>
<td>8464002</td>
<td>8635812</td>
<td>8292434</td>
<td>171810</td>
<td>171560</td>
<td>171689</td>
</tr>
<tr>
<td>RF Module</td>
<td>Total CCAs</td>
<td>0.5</td>
<td>20%</td>
<td>0.6</td>
<td>0.4</td>
<td>8464002</td>
<td>8532808</td>
<td>8368559</td>
<td>68806</td>
<td>95343</td>
<td>82074</td>
</tr>
</tbody>
</table>

In this example, it can be seen that dithering the number of PCBs in the Receiver had roughly twice the impact to the overall cost as that in the RF Module. Clearly the Receiver is more SENSITIVE to this parameter.
Cost Sensitivity Data for Sample Cost Model – Uniform Dither Factor

Cost sensitivity algorithm was applied to every Impactful Parameter in the sample cost model and calculated all cost sensitivities.

Includes: Impactful Parameters, dither amount (20%), dither “up” & dither “down” Parameter values, overall system cost, delta “mid” & delta “range”, ranking and color coded indicators. Ten most Impactful Parameters are Red, the next ten as Yellow, the next ten as Green, and the remainder as uncolored,
Cost Deltas vs. Parameters for All Parameters

Sorted By Most Impactful Parameters

All System Sensitivities

Top 30 Cost Sensitivities

Results of Cost Sensitivity Algorithm on Sample Cost Model using Uniform dither factor
Developing the Cost Algorithm

KSMs
One significant issue requiring resolution was the uniform dither factor of 20% for every Parameter. A uniform dither factor is insufficient and may yield misleading results.

To overcome the limitation, a set of Key Size Metrics, or KSMs, was developed. The KSMs would specify a unique value (other than a uniform 20%) for each Parameter.

<table>
<thead>
<tr>
<th>Expected Parameter Sequence</th>
<th>New KSMs to yield the expected sequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total CCAs</td>
<td>20%</td>
</tr>
<tr>
<td>Weight</td>
<td>60%</td>
</tr>
<tr>
<td>Integrated Components per PCB</td>
<td>5%</td>
</tr>
<tr>
<td>Clock Speed</td>
<td>20%</td>
</tr>
<tr>
<td>PCB Size</td>
<td>40%</td>
</tr>
<tr>
<td>Discreet Components per PCB</td>
<td>10%</td>
</tr>
<tr>
<td>Volume</td>
<td>75%</td>
</tr>
</tbody>
</table>
Developing the Cost Algorithm

Apply KSMs to Sample Cost Model
### Cost Sensitivity Data for Sample Cost Model – Using KSMs

Cost sensitivity algorithm was applied to every Impactful Parameter in the sample cost model and calculated all cost sensitivities. 

Includes: Impactful Parameters, dither factor (KSMs), dither “up” & dither “down” Parameter values, overall system cost, delta “mid” & delta “range”, ranking and color coded indicators. Ten most Impactful Parameters are Red, the next ten as Yellow, the next ten as Green, and the remainder as uncolored.
Cost Deltas vs. Parameters for All Parameters

Sorted By Most Impactful Parameters

Cost Deltas vs. Parameters

Results of Cost Sensitivity Algorithm on Sample Cost Model using KSM dither factors

Top 30 Cost Sensitivities

All System Sensitivities
Application of the Cost Algorithm

Using The Results, ROI
How can a system design be optimized in terms of performance and cost early on in the life cycle of a Program?

Modify a reasonable set of Impactful Parameters, observe affect to overall system cost.

The top five most impactful parameters were considered.

<table>
<thead>
<tr>
<th>Component</th>
<th>Parameter</th>
<th>Rank of impact</th>
<th>Parameter &quot;Was&quot;</th>
<th>Parameter &quot;Try&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Processing</td>
<td>Total CCAs</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Converter &amp; Noise Reduction</td>
<td>Total CCAs</td>
<td>2</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Receiver</td>
<td>Total CCAs</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>RF Module</td>
<td>Total CCAs</td>
<td>4</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Digital Processing Chassis</td>
<td>Weight</td>
<td>5</td>
<td>18</td>
<td>17</td>
</tr>
<tr>
<td>Rcv Chassis</td>
<td>Weight</td>
<td>6</td>
<td>15</td>
<td>14</td>
</tr>
</tbody>
</table>
By simultaneously adjust all top five most impactful parameters, the overall system cost has been significantly affected.
An achievable percentage improvement of 21%, Significant impact!

Another way to interpret result is in terms of Return On Investment, or ROI. In order to modify a Parameter value, it is necessary to expend some resources in order to achieve the new value. In this case, if the System Designer remains below a $1.78M dollar investment then the project, overall, would demonstrate an improvement. Anything less than $1.78M contributes to profit margin.
Summary

This paper documents the generation of a cost sensitivity algorithm of the various Components in a System in order to analyze a System and determine which Subsystem Components in a chosen design solution have the highest sensitivity to cost for the overall System and highlights the areas to which a System Designer could apply focus in order to reduce the overall System cost early on in the life cycle of a Program. It was shown that a cost sensitivity algorithm was developed and was applied to a sample cost model. The results demonstrated which Component Parameters were most sensitive, and the biggest cost drivers in the System design. And finally, Return On Investment, or ROI, was calculated to suggested a Trade Study budget for achieving the potential cost improvements. The potential cost improvements with some realistic design alternatives was demonstrated to be a 21% improvement in overall system cost which is clearly a significant improvement.
Questions ?