The Cost of Trade-Offs: Generative Design Decision Making with aPriori

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Sr Product Manager - Autodesk

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Director Product Management - aPriori
About the speaker

Brian M. Frank

Brian M. Frank is Sr. Product Line Manager for Generative Design solutions at Autodesk. Having held various roles within Autodesk since joining in 2008, Brian focuses on the development of simulation products and next generation technologies, including finite element analysis (FEA), computational fluid dynamics (CFD), and Generative Design offerings from Autodesk.
About the speaker

Carsten Hochmuth, Ph.D.

Carsten is a Director of Product Management at aPriori Technologies, where he has been instrumental in leading the company’s move to the cloud. He has over twenty-five years of experience in leadership roles in product management, industry marketing and business development in enterprise software, robotics and industrial machinery companies, including PTC, Endeca, Autodesk, Symbotic and T-Splines. Carsten secured his BS, MS and PhD in Mechanical Engineering from MIT.
The ultimate goal for any engineering activity is to strike the right balance between performance and cost to produce for a given design challenge or market opportunity.

Engineers are limited in the time and energy they can spend on any design problem to fully explore the options that encompass the design space.
Design Option on a Price Performance Curve

- Low Cost/Low Performance
- High Cost/High Performance
Price Performance Curve
Traditional Design Process
Generative Design Process

GENERATIVE DESIGN

MULTIPLE VALIDATED MANUFACTURABLE OPTIONS

DESIGN TO MAKE

PRODUCE

TIME TO MARKET

ITERATION PHASE

DESIGN TO PRODUCTION

PRODUCTIVITY INCREASE
Fusion 360 Generative Design capability enables the rapid creation and exploration of design options, empowering design teams to determine the tradeoffs they want to make along the price/performance curve.
Costing & Product Development

Costing is an important component of the Product Journey from Ideation to Production.
2.5 Axis Generative
Weight: 2.3 kg (-23%) / Safety Factor: 2.2
Cost: $130

3 Axis Generative
Weight: 2.3 kg (-23%) / Safety Factor: 2.3
Cost: $145

Human Design
Weight: 3 kg / Safety Factor: 2.7
Cost: $160

Additive Generative
Weight: 2.2 kg (-26%) / Safety Factor: 2
Cost: $418
Trade-off Analysis

Weight Saving

Affordability

Strength

- Human Design
- Additive
- 3-Axis
- 2.5-Axis
Safety Factor vs Mass

- **Additive**
- **3 Axis**
- **2.5 Axis**
- **Human Design**
Costing for Decision Making

* Batch of 1000 pieces, per piece cost estimate from aPriori
“I have been talking for years about the importance of engineers to design for cost optimization. You are the 1st to show me something that aligns with my vision of helping engineers make smarter financial decisions, who do you work for again?”

-VP Of Engineering, Aerospace Manufacturer
COSTING | Early Stage Technology Strategy

Costs across material, MFG method, shape of geometry, production volume

User Input → Geometry Solve → Cost Solver → Relative Cost

Filter

$0 → $XX
Cost Of Methods and Volumes

Additive Manufacturing
AlSi10Mg
0.19 kg (75% reduction)

CNC
Al6061
0.25 kg (66% reduction)

Die Casting
AlSi10Mg
0.21 kg (72% reduction)
Visual Similarity and Cost
Going Further with aPriori

Getting a Deeper Understanding of Cost Drivers
Introduction to aPriori

Area of Focus:
- Real-time visibility to the manufacturability and cost of manufactured products
- Move from concept to customer faster with significant hard dollar ROI
- Higher quality products, shorter time to market, most competitive costs

Technology:
- Single database architecture to standardize costing methods across global operations
- Geometric Cost Drivers pulled directly from 3D CAD Models to accelerate creation of cost estimates
- 200+ Physics-based Mechanistic Cost Models available out-of-the-box
- 79 Regional Data Libraries with Materials, Machines & Overhead costs
- Available in On-Premise or Cloud Deployments

Location:
- Headquartered in Concord, MA
- Global customer base

Selected Customers
What Makes Us Different?

Geometry Extraction
Allows designers & engineers to do early stage costing to identify manufacturability issues and avoid cost

Manufacturing Simulations
Provides accurate analysis of real-world manufacturing conditions; not comparisons to outdated supplier quotes

Regional Data
Enables quick evaluation of manufacturing options at in-house or supplier facilities using region specific cost data for machines, materials and overhead

Cost Collaboration
Single database architecture allows Cost Engineers, Designers, and Buyers to collaborate and evolve cost estimates as a design takes form
Connected, Collaborative Applications

- Design Engineer
- Team Lead / Manager
- Cost Engineer / Sourcing
- Stakeholder / Supplier
Over 200 Cost Models
Available Out of the Box

- Sheet Metal Fabrication & Stamping
- Bar & Tube Fab
- Plastic Molding
- Casting
- Machining
- Gear Making
- Forging
- Powder Metal
- Additive
- Chemical Milling
- PCBA & Wire Harness
- Assembly

Surface Treatments
Heat Treatments
Anodizing
Clean, Test & Inspect
Packaging & Logistics
aPriori Use Cases

A range cost estimate in Generative Design is only the beginning

- With the Fusion CAD model from your generative design study:
  - Review the cost in specific regions
  - Explore cost impact and tradeoff at different production volumes
  - Cost against your own configured virtual production environments

- Detailed manufacturability and cost driver analysis for all your designs during NPI

- Accelerate value engineering initiatives

- Bring detailed cost details to the table with suppliers for fact-based negotiation

- Improve your quoting speed and win ratio
Design & Manufacturability Guidance

aPriori evaluates the design for manufacturability and cost drivers

**Design Guidance**

- **Warnings:** 5
- **Guidance Issues:** 19
- **GCDs with Tolerances:** 0

**Cycle Time**

- Side Milling
- Length/Diameter Ratio
- Machining Setups
- Holes and Fillets
- Threading
Material Cost

aPriori calculates the raw material required for the selected process.

For example, in a sheet metal part, the unfolded blank shape and the nesting of that blank drive the utilization and material required.

<table>
<thead>
<tr>
<th>Material &amp; Utilization</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Material:</strong></td>
</tr>
<tr>
<td>Steel, Cold Worked, AISI 1020</td>
</tr>
<tr>
<td>Finish Mass (kg):</td>
</tr>
<tr>
<td>Utilization (%):</td>
</tr>
</tbody>
</table>

Selected Sheet: 1.90 mm x 1219 mm x 3048 mm
Blank Size (mm): 625.2651 x 404.8237
Parts Per Sheet: 13
Processing Cost

aPriori evaluates all the possible routings to manufacture a part or assembly at the selected process and volume.

For each routing sequence the cycle time is evaluated and the result manufacturing cost. The lowest cost feasible routing is selected automatically.
Investment Cost

aPriori calculates the cost of hard tooling, fixturing, programming required to manufacture the part in the selected process.

Investment cost is amortized over the production volume of the part.

| Material Cost (USD):   | 0.15 |
| Piece Part Cost (USD): | 1.15 |
| Fully Burdened Cost (USD): | 2.85 |
| Total Capital Investments (USD): | 16,985.52 |
Explore design alternatives & cost tradeoffs

![Image of a bracket design]

<table>
<thead>
<tr>
<th>Component</th>
<th>Initial</th>
<th>BRACKET V...</th>
<th>BRACKET V...</th>
<th>BRACKET V...</th>
<th>BRACKET V...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum, Stock, A...</td>
<td>0.22</td>
<td>0.21</td>
<td>-5.55%</td>
<td>0.20</td>
<td>0.23</td>
</tr>
<tr>
<td>Aluminum, Cast, A...</td>
<td>6.83</td>
<td>31.24</td>
<td>357.28%</td>
<td>33.78</td>
<td>93.96</td>
</tr>
<tr>
<td>Aluminum A15/10Mg</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Material Stock / Base</td>
<td>4,181.87</td>
<td>1,276.58</td>
<td>-68.47%</td>
<td>13,535.13</td>
<td>414.05</td>
</tr>
<tr>
<td>Melting / Die Cast</td>
<td>3.16%</td>
<td>2.10</td>
<td>-93.50%</td>
<td>32.06%</td>
<td>86.81</td>
</tr>
<tr>
<td>Metal Sintering / Si</td>
<td>14.59%</td>
<td>9.72</td>
<td>-69.35%</td>
<td>12.02%</td>
<td>32.53</td>
</tr>
<tr>
<td>Melting / Stock Cor</td>
<td>9.41%</td>
<td>2.95</td>
<td>-73.36%</td>
<td>24.83%</td>
<td>67.17</td>
</tr>
<tr>
<td>Indirect Overhead (USD)</td>
<td>13.08%</td>
<td>10.90%</td>
<td>-52.86%</td>
<td>12.79%</td>
<td>34.60</td>
</tr>
<tr>
<td>Components (USD)</td>
<td>0.50%</td>
<td>23.94</td>
<td>3.982.00%</td>
<td>0.10%</td>
<td>0.28</td>
</tr>
<tr>
<td>Assembly Processes (USD)</td>
<td>22.74%</td>
<td>31.00%</td>
<td>-22.93%</td>
<td>18.17%</td>
<td>49.16</td>
</tr>
<tr>
<td>Fully Burdened Cost (USD)</td>
<td>26.80%</td>
<td>20.66</td>
<td>391.48%</td>
<td>37.40%</td>
<td>18.86</td>
</tr>
<tr>
<td>Target Cost (USD)</td>
<td>117.84</td>
<td>66.63</td>
<td>-43.46%</td>
<td>270.55</td>
<td>129.58</td>
</tr>
<tr>
<td>Total Capital Investment (USD)</td>
<td>1,172.93</td>
<td>47,878.89</td>
<td>3,982.00%</td>
<td>160.17</td>
<td>37,256.98</td>
</tr>
</tbody>
</table>

Cost Results:
- Material (USD): 27.35% 32.23 3.31% 2.10 93.50%
- Labor (USD): 26.92% 31.72 14.59% 9.72 69.35%
- Direct Overhead (USD): 9.41% 11.09 4.43% 2.95 73.36%
- Indirect Overhead (USD): 13.08% 15.41 10.90% 7.25 52.86%
- Investment (USD): 0.50% 0.59 35.93% 23.94 3.982.00%
- Other (USD): 22.74% 26.80 31.00% 20.66 22.93%
- Components (USD): 117.84 66.63 43.46%
- Assembly Processes (USD): 270.55 129.58 52.24%
- Fully Burdened Cost (USD): 160.17 37,256.98 3.076.41%
Track to Cost Target
aPriori Use Cases Within the Value Stream

1. Reduce Time to Quote – “First In” Advantage
   - Increase Win Rate
   - More Quotes with Same Resources

2. Increase Win Rate
   - Design
   - Forecasting New Product Cost
   - Reduce Time-to-Market

3. More Quotes with Same Resources
   - Time Standard Development
   - Capital Justification
   - Make vs. Buy
   - Request for Quote Response

SALES  R&D  DESIGN  SOURCING  MFG  VAVE

1. Assessing Early Concept Costs
   - Developing New High Margin Products

2. Should Cost Analysis
   - Outlier Analysis
   - More Informed Negotiation
   - Analyzing Greater Percent of Buy

3. Reducing Current Product Costs
   - Costing Engineering Changes
   - VAVE Opportunity Identification
   - Improving Costs for the Next Program
Questions?