Simulation Optimization
Decision Support System for
Ship Panel Line Operations

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Case Study Track
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Broad objective: Maximize shipyard throughput, subject to customer due date

Problem*: U.S. shipyards take twice as long to build comparable ships; 1/3 as productive as the Japanese, 1/2 as productive as the Europeans

- Build ships faster and cheaper
- Increase throughput of the yard and sector; increase profit
- Reduce lead time
- Improve the use of key resources
- Employ best practices
- Effectively deal with variability

Focus on the shipyard bottleneck: Panel Shop
Every panel is unique → extreme variability in work content
Project overview

• **Objective:** provide a means to understand and assess the impact on shop performance of changes in:
  – resources,
  – operations practices,
  – panel characteristics,
  – sequence, etc.

• **Components:**
  – Discrete-event simulation model of panel shop
  – Optimizer to determine best sequence for producing panels
  – DSS so the simulation model and optimizer could be used by planners and shop floor supervisors
Overview of Simulation-Optimization Decision Support System
ProModel simulation model captures shop behavior

Model considers:
• Panel size and conveyor capacity
• Work content
• Resource availability
• Work assignments
• Operational rules
• Downtime
• Task variability
• Shift schedule
• Relevant measures of performance

Model runtime: approximately 5 seconds to process 154 panels (~13 weeks in real time)
Model accurately captures shop behavior

*Hours to complete* is based on observation; the number of panels that had exited at a specified time; e.g., at time 697, 52 panels had been competed.

*Model Complete* is the time a panel left the system in the model; e.g. Panel 52 was completed at time 681.
**Workstation processing times based on work standards and panel characteristics**

| Standards       | Panel DDG 356
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>min/seam</td>
<td>min/ft</td>
</tr>
<tr>
<td>Sweep</td>
<td>3</td>
</tr>
<tr>
<td>Flux</td>
<td>5</td>
</tr>
<tr>
<td>Wire</td>
<td>12</td>
</tr>
<tr>
<td>Align</td>
<td>30</td>
</tr>
<tr>
<td>Console</td>
<td>13</td>
</tr>
<tr>
<td>Weld</td>
<td>0.83</td>
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<td>Traverse return</td>
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<tr>
<td>Console</td>
<td>6</td>
</tr>
<tr>
<td>Traverse</td>
<td>0.054</td>
</tr>
<tr>
<td>Remove ram</td>
<td>2</td>
</tr>
<tr>
<td>Remove plate</td>
<td>6</td>
</tr>
<tr>
<td>Slag chips</td>
<td>2</td>
</tr>
<tr>
<td>Defect repair</td>
<td>0.72</td>
</tr>
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</table>

**Time**

- 15
- 25
- 60
- 150
- 65
- 119
- 24
- 8
- 10
- 30
- 10
- 619

![Diagram of NGSS PANEL LINE SIMULATION](image)
Simulation model incorporates dynamic resource assignments

**Panel Weld Time (min.)**

<table>
<thead>
<tr>
<th>Hull</th>
<th>Unit</th>
<th>SA</th>
<th>SSAW</th>
<th>Topside SAW</th>
<th>Backside SAW</th>
<th>Layout</th>
<th>FCAW 2</th>
<th>FCAW 1</th>
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<tr>
<td>5250</td>
<td>315</td>
<td>01-03</td>
<td>288</td>
<td>719</td>
<td>230</td>
<td>244</td>
<td>290</td>
<td>311</td>
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<tr>
<td>5250</td>
<td>323</td>
<td>01-01</td>
<td>276</td>
<td>152</td>
<td>314</td>
<td>235</td>
<td>341</td>
<td>291</td>
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<tr>
<td>5250</td>
<td>323</td>
<td>01-02</td>
<td>309</td>
<td>700</td>
<td>260</td>
<td>139</td>
<td>228</td>
<td>37</td>
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<tr>
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<td>323</td>
<td>01-03</td>
<td>291</td>
<td>295</td>
<td>63</td>
<td>220</td>
<td>145</td>
<td>414</td>
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<tr>
<td>5250</td>
<td>332</td>
<td>01-01</td>
<td>487</td>
<td>428</td>
<td>370</td>
<td>170</td>
<td>343</td>
<td>526</td>
</tr>
<tr>
<td>5250</td>
<td>324</td>
<td>01-01</td>
<td>264</td>
<td>426</td>
<td>577</td>
<td>223</td>
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<td>721</td>
<td>753</td>
<td>360</td>
<td>859</td>
<td>154</td>
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</table>
Optimal sequence based on genetic algorithm

- Modified evolutionary strategy
- Fitness function
  - based on total weld feet, make span, days late for each job
  - value is evaluated for each combination using the simulation model
- DSS manages optimization process, including evaluation of each solution by the discrete-event simulation model
- Sample run for a set of 50 panels
## Example analyses

Percent change in makespan (time to complete panel set)

### Machine Utilization

<table>
<thead>
<tr>
<th>Personnel Utilization</th>
<th>100</th>
<th>90</th>
<th>80</th>
<th>70</th>
<th>60</th>
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<tbody>
<tr>
<td></td>
<td>100%</td>
<td>90%</td>
<td>80%</td>
<td>70%</td>
<td>60%</td>
</tr>
<tr>
<td>100</td>
<td>6.0%</td>
<td>5.8%</td>
<td>5.7%</td>
<td>5.2%</td>
<td>4.4%</td>
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<tr>
<td>95</td>
<td>3.9%</td>
<td>3.9%</td>
<td>3.8%</td>
<td>3.2%</td>
<td>2.7%</td>
</tr>
<tr>
<td>85</td>
<td>0.0%</td>
<td>-0.6%</td>
<td>-0.6%</td>
<td>-1.6%</td>
<td>-1.1%</td>
</tr>
<tr>
<td>70</td>
<td>-7.7%</td>
<td>-7.4%</td>
<td>-8.3%</td>
<td>-8.5%</td>
<td>-9.0%</td>
</tr>
</tbody>
</table>

Base Case: Personnel Utilization = 85%, Machine Utilization = 100%

### Process Variability

<table>
<thead>
<tr>
<th>Personnel Utilization</th>
<th>none</th>
<th>-5/+10</th>
<th>-10/+20</th>
<th>-25/+50</th>
<th>-25/+100</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>6.5%</td>
<td>6.0%</td>
<td>5.4%</td>
<td>3.0%</td>
<td>-4.8%</td>
</tr>
<tr>
<td>85</td>
<td>-0.1%</td>
<td>0.0%</td>
<td>-1.2%</td>
<td>-3.4%</td>
<td>-11.7%</td>
</tr>
<tr>
<td>70</td>
<td>-7.1%</td>
<td>-7.7%</td>
<td>-8.4%</td>
<td>-11.6%</td>
<td>-20.0%</td>
</tr>
</tbody>
</table>

Base Case: Personnel Utilization = 85%, Process Variability = -5% / +10%
Basic DSS architecture

• Support planner-level and shop-floor-level decisions
  – Easy-to-use interfaces
  – Intuitive and relevant output
  – Model operations transparent to users
• Driven by NGSS data; responsive to changes in data
• Sequence:
  – based on shop-floor behavior, capabilities, and constraints
  – performance assessed using simulation model
  – generated by genetic algorithm
• Provides work assignments required to meet optimal sequence
DSS interface

Model* Selection

*run in ProModel or QUEST

Operations parameters

Panel selection

Optimal sequence
DSS output
Future directions: application across a sector

Decision Makers

Decision Support System

Models

Suppliers → Fabrication → Panel Line → 225 → CSA, Outfitting, etc. → Customers

Real System

Modeling