Development of Lean Enterprise Simulation Tools

NSRP Program

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Northrop Grumman Newport News
Topics

- Project Overview
- Supply Chain Integration
- Design Processes
- Scheduling
- Ship Repair
- Value Stream Mapping
- Simulation Kits – Cost and Availability
- Train-the-Trainer Program - Cost
Lean Enterprise Simulation Project - Overview

Development of simulation tools, associated training programs & kits for shipbuilding industry

Duration 16 Months

9/03 – 12/04

Phase-0 Completed

Phase-1 Completed

Lead Inst.: ODU

Shipyard: NGNN

STASR

Participating Organization
Five Areas of Need Identified by Industry

- Design Process
- Ship Repair Process
- Supply Chain Integration
- Value Stream Management
- Scheduling
Project Scope

Design and develop simulation activities in five areas to complement existing Lean training programs.

- Identified five areas of critical need.
- Develop associated training programs.
- Develop simulation kits.
- Disseminate the results.
- Develop and deploy a web site.
Benchmarking Simulation Activity – All five areas

Phase - I
Traditional Manufacturing
Large Batch, Push System

Collect data and compare

Phase - II
Implement LEAN Tools and
Compare Performance Metrics

Collect data and compare

Phase - III
Implement LEAN Tools and
Compare Performance Metrics

Collect data and compare

Lean Enterprise
LEAN ENTERPRISE SIMULATION AREAS

- Value Stream Mapping
- Ship Repair Process
- Scheduling
- Supply Chain Integration
- Design Process
**ISSUES IN SUPPLY CHAIN**

<table>
<thead>
<tr>
<th>#</th>
<th>ISSUES</th>
<th>LEAN TOOLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Scheduling Problem</td>
<td>Pull, Integrate Planning &amp; Sourcing with suppliers, information sharing</td>
</tr>
<tr>
<td>2</td>
<td>Adversarial relationship with supplier</td>
<td>Team - Sharing information, long-term commitment, communication</td>
</tr>
<tr>
<td>3</td>
<td>No involvement of supplier in design.</td>
<td>Co-location</td>
</tr>
<tr>
<td>4</td>
<td>Long lead-time</td>
<td>Pull, Group technology</td>
</tr>
<tr>
<td>5</td>
<td>High costs</td>
<td>Batch size reduction.</td>
</tr>
<tr>
<td>6</td>
<td>Inventory very high</td>
<td>POUS, Pull, 5S, Batch reduction, TPM</td>
</tr>
<tr>
<td>7</td>
<td>Challenge in synchronizing flow with suppliers.</td>
<td>Pull, Kanban, Takt time.</td>
</tr>
<tr>
<td>8</td>
<td>Vendors furnishing information late</td>
<td>Map information flow, (reduce paperwork, improve scheduling)</td>
</tr>
<tr>
<td>9</td>
<td>Irregular performance</td>
<td>Built in quality, mistake proofing.</td>
</tr>
<tr>
<td>10</td>
<td>Higher price to US shipyards</td>
<td>Co-designing, sharing information, long-term commitment</td>
</tr>
<tr>
<td>11</td>
<td>Shrinking choice of vendors</td>
<td>Vendor development</td>
</tr>
<tr>
<td>12</td>
<td>Many engineering changes</td>
<td>Concurrent Engineering, Co-location.</td>
</tr>
</tbody>
</table>
The simulation is done in 3 phases
The first phase simulates the traditional supply chain process
Partial Lean implementation in shipyard in first phase
Lean tools are implemented through 2nd and 3rd phase
Impact of Lean implementation is studied through performance metrics
This simulation includes 2 primary suppliers and 2 secondary suppliers
A variability wheel is used to inject random variations in the simulation
Supply Chain

ROOM LAYOUT - PHASE - I

Secondary Supplier - 3

Primary Supplier - 1

Primary Supplier - 2

Secondary Supplier - 4

Planning / Buyer

Engineering

Whs – 1

Sub-Assembly - 1

Assembly

Whs – 2

Whs – 3

Sub-Assembly - 2

Central Warehouse

Shipyard
Supply Chain

PERFORMANCE METRICS - PILOT – 16th JULY

- Lead-time reduces as we go from phase-1 to phase-3
- There is a 30% reduction in overall lead time.
- Number of quality checks decrease from 25 in phase-1 to 2 in phase-3.
- Space utilized by warehouses decreases.
- Cycle time decreases.
KEY BENEFITS DEMONSTRATED DURING PILOT SESSIONS

- Reduction in Lead time from phase-1 to phase-3.
- Decrease in number of quality checks and cost of quality checks.
- Reduction in space utilized by warehouses.
- On-time delivery in phase-3.
- Decrease in cycle times due to improved communication.
Design Processes

- Value Stream Mapping
- Ship Repair Process
- Scheduling
- Supply Chain Integration
- Design Process

LEAN ENTERPRISE SIMULATION
### Issues in Design Process

<table>
<thead>
<tr>
<th></th>
<th>ISSUES</th>
<th>LEAN TOOLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lack of Communication</td>
<td>Communication, IPPD, CAD/CAM System, Co-location</td>
</tr>
<tr>
<td>2</td>
<td>Unnecessary Review/ Duplicate Review</td>
<td>TQM, Quality at Source</td>
</tr>
<tr>
<td>3</td>
<td>Over the Wall</td>
<td>Concurrent Engineering /IPPD</td>
</tr>
<tr>
<td>4</td>
<td>Lack of Standardization</td>
<td>DFM</td>
</tr>
<tr>
<td>5</td>
<td>Design for Maintenance</td>
<td>DFM</td>
</tr>
<tr>
<td>6</td>
<td>Lead Time</td>
<td>Group Technology</td>
</tr>
<tr>
<td>7</td>
<td>Batch Flow</td>
<td>Single Piece Flow</td>
</tr>
<tr>
<td>8</td>
<td>Lack of Line Balancing</td>
<td>Takt time, GT</td>
</tr>
<tr>
<td>9</td>
<td>Functional Processing</td>
<td>Cellular</td>
</tr>
</tbody>
</table>
Role of Various Departments

Calculate:
- $F_r = \frac{V}{\sqrt{g * l}}$
- $C_B = \text{Use Chart 2}$
- $\text{SHP} = \frac{\text{TEU} \times \text{KT}}{1000}$
- Weights: Using charts 4, 5, 6
- Consumables = 0.50 LBS
- $\text{SHP Hrs}$
- $\text{Draft} = \frac{35 \times \Delta}{L \times B \times C_B}$

Calculate: Bending Stress $\sigma$

$\sigma = \frac{M \times y}{I}$
• Phase 1 demonstrates the traditional design process
• There will be confusion and chaos due to lack of communication, no visual signals, no accountability and no pull system.
- Communication, Co-location
- Integrated Product and Process Design (IPPD)
- Concurrent Engineering
- Single Piece Flow
### Performance Metrics from NGNN Pilots

<table>
<thead>
<tr>
<th>PERFORMANCE CRITERIA</th>
<th>Phase I</th>
<th>Phase II</th>
<th>Phase III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total # of Employees</td>
<td>14</td>
<td>14</td>
<td>13</td>
</tr>
<tr>
<td>Lead Time (to complete one order)</td>
<td>35</td>
<td>24</td>
<td>10</td>
</tr>
<tr>
<td><strong>Cycle Time</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Customer Order</td>
<td>0.15</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>Conceptual Design</td>
<td>2.4</td>
<td>2.5</td>
<td></td>
</tr>
<tr>
<td>Preliminary Design</td>
<td>14</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Drafting</td>
<td>1.1</td>
<td>1.3</td>
<td></td>
</tr>
<tr>
<td>Detailed Design</td>
<td>6</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Analysis</td>
<td>7</td>
<td>4.2</td>
<td></td>
</tr>
<tr>
<td>Supervisor</td>
<td>3.5</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Number of Reviews</td>
<td>5</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Trips made by the Transporter</td>
<td>10</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>Paper Work- # of files forwarded to next Dept.</td>
<td>5</td>
<td>2</td>
<td>ERP</td>
</tr>
</tbody>
</table>

---

**Design Process**

**ERP System**

**Concurrent Operations**
# Performance Metrics for Preliminary Design Department

<table>
<thead>
<tr>
<th>Cycle Time</th>
<th>Round 1</th>
<th>Round 2</th>
<th>Round 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preliminary Design #1</td>
<td>2.3</td>
<td>2</td>
<td>ERP System</td>
</tr>
<tr>
<td>Preliminary Design #2</td>
<td>1.3</td>
<td>2.2</td>
<td>Concurrent Operations</td>
</tr>
<tr>
<td>Preliminary Design #3</td>
<td>6.4</td>
<td>3.2</td>
<td></td>
</tr>
<tr>
<td>Preliminary Design #4</td>
<td>3.2</td>
<td>1.4</td>
<td></td>
</tr>
</tbody>
</table>

**Cycle Time for Preliminary Design Department**

![Cycle Time Chart](chart.png)
• The lead time dropped from 35 minutes in phase-I to 24 minutes in Phase II and to 10 minutes in Phase III.
• Total simulation time also went down for all phases due to refinement.
• Fewer errors due to clarifications and changes in instructions.
• Introduction of WIP in Analysis Department reduced the idle time during the beginning of simulation.
• Introduction of the third order kept Conceptual Design Department and Preliminary Design Department busy till the end of simulation.
Scheduling

Value Stream Mapping

Ship Repair Process

Lean Enterprise Simulation

Scheduling

Design Process

Supply Chain Integration
Components of Model used in Simulation

MODULE 1
AC-UNIT
MODULE 2
WATER TANK
MODULE 3
FUEL TANK
ENGINE
PROPELLER SHAFT
MODULE 4
## Issues in Scheduling

<table>
<thead>
<tr>
<th>Issues</th>
<th>Lean Tools</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Lack of Communication</td>
<td>Cross Functional Teams, Co-location.</td>
</tr>
<tr>
<td>2 Artificial variability, machine breakdown</td>
<td>Time buffer, TPM.</td>
</tr>
<tr>
<td>3 Material planning and capacity planning</td>
<td>Cross functional teams.</td>
</tr>
<tr>
<td>4 Sequential scheduling</td>
<td>Spatial scheduling</td>
</tr>
<tr>
<td>5 Demand variation</td>
<td>Supermarket</td>
</tr>
<tr>
<td>6 Workload Distribution</td>
<td>Line balancing, takt time</td>
</tr>
<tr>
<td>7 Priority Management</td>
<td>Cradle to grave approach, Cross functional teams</td>
</tr>
<tr>
<td>8 Disruptions in schedule</td>
<td>Dynamic scheduling, Time buffer, Communication between suppliers and schedulers</td>
</tr>
</tbody>
</table>
Room Layout for Phase 1

Phase 1 demonstrates the following problems -

- Lack of communication
- Demand variability, Capacity planning, Resource planning
- Spatial management, Priority management
### Results of pilots (NGNN-Pilot 2)

#### Scheduling

<table>
<thead>
<tr>
<th></th>
<th>Phase I</th>
<th>Phase II</th>
<th>Phase III</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>crane utilization</strong></td>
<td>3.2</td>
<td>1.5</td>
<td>1.4</td>
</tr>
<tr>
<td><strong>drydock cycle time</strong></td>
<td>17</td>
<td>5</td>
<td>4.5</td>
</tr>
<tr>
<td><strong>cycle time at planning dept</strong></td>
<td>0.3</td>
<td>0.3</td>
<td>0.22</td>
</tr>
<tr>
<td><strong>cycle time at production dept</strong></td>
<td>0.2</td>
<td>0.15</td>
<td>0.11</td>
</tr>
<tr>
<td><strong>cycle time at purchasing dept</strong></td>
<td>0.4</td>
<td>0.2</td>
<td>0.19</td>
</tr>
<tr>
<td><strong>cycle time at WS1</strong></td>
<td>0.5</td>
<td>1.8</td>
<td>1.5</td>
</tr>
<tr>
<td><strong>cycle time at WS2</strong></td>
<td>2.1</td>
<td>5</td>
<td>3.5</td>
</tr>
<tr>
<td><strong>cycle time at WS3</strong></td>
<td>1</td>
<td>1</td>
<td>0.8</td>
</tr>
<tr>
<td><strong>Inventory holding cost of AC Unit (50$/min)</strong></td>
<td>50</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td><strong>Inventory holding cost of Heat Exchanger (50$/min)</strong></td>
<td>100</td>
<td>25</td>
<td>35</td>
</tr>
<tr>
<td><strong>Inventory holding cost of Water tank (50$/min)</strong></td>
<td>75</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td><strong>Inventory holding cost of Fuel tank (30$/min)</strong></td>
<td>60</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td><strong>Inventory holding cost of Engine (50$/min)</strong></td>
<td>80</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td><strong>Inventory holding Cost of propeller shaft (20$/min)</strong></td>
<td>80</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td><strong>Inventory holding cost of propeller (20$/min)</strong></td>
<td>90</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td><strong>TOTAL HOLDING COST OF ITEMS</strong></td>
<td><strong>$535.00</strong></td>
<td><strong>$125.00</strong></td>
<td><strong>$135.00</strong></td>
</tr>
<tr>
<td><strong>cycle time at warehouse</strong></td>
<td>11</td>
<td>7.8</td>
<td>4.5</td>
</tr>
<tr>
<td><strong>Total lead time</strong></td>
<td>17.5</td>
<td>13</td>
<td>10</td>
</tr>
<tr>
<td><strong>Drydock cost ($100/minute)</strong></td>
<td><strong>$1,700.00</strong></td>
<td><strong>$500.00</strong></td>
<td><strong>$450.00</strong></td>
</tr>
<tr>
<td><strong>Work Stations Cost ($25/minute)</strong></td>
<td><strong>$90.00</strong></td>
<td><strong>$195.00</strong></td>
<td><strong>$145.00</strong></td>
</tr>
<tr>
<td><strong>Crane cost ($50/minute)</strong></td>
<td><strong>$160.00</strong></td>
<td><strong>$75.00</strong></td>
<td><strong>$70.00</strong></td>
</tr>
<tr>
<td><strong>Warehouse Cost ($50/minute)</strong></td>
<td><strong>$550.00</strong></td>
<td><strong>$390.00</strong></td>
<td><strong>$225.00</strong></td>
</tr>
<tr>
<td><strong>TOTAL COST</strong></td>
<td><strong>$2,500.00</strong></td>
<td><strong>$1,160.00</strong></td>
<td><strong>$890.00</strong></td>
</tr>
</tbody>
</table>

#### PERFORMANCE ANALYSIS

- As we implemented pull scheduling in pilot 2, there is a reduction in inventory hold cost for parts at warehouse.
- Cycle time at workstation 2 is reduced by 30% in phase 3 as compared to phase 2 after we implement dynamic scheduling.
Results of pilots (NGNN-2)

Drydock Cycle time

Cycle time decreases due to implementation of dynamic scheduling.

Crane Utilisation

CT at WS 1

Simulation Phase Number
Key Benefits Demonstrated During Pilot Sessions

- Reduction in the total cost for building in phase 2 and 3 compared to phase 1 as we implement lean principles in phase 2 and 3.
- Reduction in inventory holding cost of warehouse as we implement pull scheduling in phase 2 and 3.
- Reduction of cycle time of dry-dock in phase 2 and 3 as we implement spatial scheduling and 5s.
- Cycle time of workstation 2 reduces as we implement line balancing at workstations.
- Sub assemblies are done at workstations as part of dynamic scheduling which reduces the cycle time of dry-dock.
Ship – Repair Process

Value Stream Mapping

Ship Repair Process

LEAN ENTERPRISE SIMULATION

Scheduling

Supply Chain Integration

Design Process
<table>
<thead>
<tr>
<th>No.</th>
<th>Important Issues</th>
<th>Lean Tools</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Emergent Repair</td>
<td>Cradle to grave approach, Use of historical data</td>
</tr>
<tr>
<td>2</td>
<td>Job Sequencing/ Pacing</td>
<td>Pull, TAKT time, Multiple skills</td>
</tr>
<tr>
<td>3</td>
<td>Multiple Source Planning</td>
<td>Communication</td>
</tr>
<tr>
<td>4</td>
<td>Resource Setup and Changeover</td>
<td>Setup reduction</td>
</tr>
<tr>
<td>5</td>
<td>Excessive part / people travel</td>
<td>Cellular layout</td>
</tr>
<tr>
<td>6</td>
<td>Unrealistic Planning</td>
<td>Cradle to grave approach, Use of historical data</td>
</tr>
<tr>
<td>7</td>
<td>Space Management</td>
<td>5S, POUS</td>
</tr>
<tr>
<td>8</td>
<td>Lack of Capacity Management</td>
<td>Capacity Management</td>
</tr>
</tbody>
</table>
Example of Repair Jobs

Ship Repair

Blasting of Ship

Painting of Ship
Room Layout - Phase - I

- Planning
- Warehouse
- Production
- Dry Dock
- Hull
- Inspection
- Waterfront Services
- Material Information

Ship Repair
### Performance Metrics - Pilot – 2nd August

**Ship Repair**

<table>
<thead>
<tr>
<th>Task</th>
<th>Phase - 1</th>
<th>Phase - 2</th>
<th>Phase - 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start Time for Replacement of Deckplate # 1 of ship 1</td>
<td>0.11</td>
<td>1</td>
<td>0.44</td>
</tr>
<tr>
<td>Finish Time for Replacement of Deckplate # 1 of ship 1</td>
<td>18.46</td>
<td>3.33</td>
<td>4.34</td>
</tr>
<tr>
<td>Start Time for Replacement of Deckplate # 3 of ship 1</td>
<td>1.5</td>
<td>0.4</td>
<td>0.2</td>
</tr>
<tr>
<td>Finish Time for Replacement of Deckplate # 3 of ship 1</td>
<td>19</td>
<td>12.12</td>
<td>6.36</td>
</tr>
<tr>
<td>Start Time for Replacement of Deckplate # 1 of ship 2</td>
<td>4.26</td>
<td>4.05</td>
<td>4.15</td>
</tr>
<tr>
<td>Finish Time for Replacement of Deckplate # 1 of ship 2</td>
<td>17.3</td>
<td>8.3</td>
<td>7.56</td>
</tr>
<tr>
<td>Start Time for Engine Overhaul</td>
<td>4.2</td>
<td>1.58</td>
<td>8.3</td>
</tr>
<tr>
<td>Finish Time for Engine Overhaul</td>
<td>16.55</td>
<td>9.07</td>
<td>6.11</td>
</tr>
<tr>
<td>Start Time for Painting and Blastng</td>
<td>8</td>
<td>8</td>
<td>7.14</td>
</tr>
<tr>
<td>Finish Time for Painting and Blastng</td>
<td>15.06</td>
<td>14.44</td>
<td>11.09</td>
</tr>
<tr>
<td>Start Time for Shaft Straightening</td>
<td>8.35</td>
<td>9.4</td>
<td>8</td>
</tr>
<tr>
<td>Finish Time for Shaft Straightening</td>
<td>9.55</td>
<td>10.22</td>
<td>8.53</td>
</tr>
<tr>
<td>Start Time for cutting Plate # 1 of ship - 1</td>
<td>5</td>
<td>0.19</td>
<td>3</td>
</tr>
<tr>
<td>Finish Time for cutting Plate # 1 of ship - 1</td>
<td>10.41</td>
<td>1.5</td>
<td>5.46</td>
</tr>
<tr>
<td>Start Time for cutting Plate # 3 of ship - 1</td>
<td>4.28</td>
<td>2.25</td>
<td>0</td>
</tr>
<tr>
<td>Finish Time for cutting Plate # 3 of ship - 1</td>
<td>10.41</td>
<td>3.56</td>
<td>1.45</td>
</tr>
<tr>
<td>Start Time for cutting Plate # 1 of ship - 2</td>
<td>5.51</td>
<td>4.45</td>
<td>5.01</td>
</tr>
<tr>
<td>Finish Time for cutting Plate # 1 of ship - 2</td>
<td>10.5</td>
<td>6.3</td>
<td>6.47</td>
</tr>
<tr>
<td>Number of Modules on which repainting was done</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Repainting Cost for one module</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Lead Time</td>
<td>22.26</td>
<td>14.89</td>
<td>11.38</td>
</tr>
<tr>
<td>Cycle Time for Replacement of Deckplate # 1 of ship - 1</td>
<td>18.35</td>
<td>2.33</td>
<td>3.9</td>
</tr>
<tr>
<td>Cycle Time for Replacement of Deckplate # 3 of ship - 1</td>
<td>17.5</td>
<td>11.72</td>
<td>6.16</td>
</tr>
<tr>
<td>Cycle Time for Replacement of Deckplate # 1 of ship - 2</td>
<td>13.04</td>
<td>4.25</td>
<td>3.43</td>
</tr>
<tr>
<td>Cycle Time for Engine Overhaul</td>
<td>12.35</td>
<td>7.49</td>
<td>5.81</td>
</tr>
<tr>
<td>Cycle Time for Painting and Blastng</td>
<td>7.06</td>
<td>6.44</td>
<td>3.95</td>
</tr>
<tr>
<td>Cycle Time for Shaft Straightening</td>
<td>1.2</td>
<td>0.82</td>
<td>0.53</td>
</tr>
<tr>
<td>Cycle Time for cutting Plate # 1 of Ship - 1</td>
<td>5.41</td>
<td>1.31</td>
<td>2.46</td>
</tr>
<tr>
<td>Cycle Time for cutting Plate # 3 of Ship - 1</td>
<td>6.13</td>
<td>1.31</td>
<td>1.45</td>
</tr>
<tr>
<td>Cycle Time for cutting Plate # 1 of Ship - 2</td>
<td>4.99</td>
<td>1.85</td>
<td>1.46</td>
</tr>
<tr>
<td>Total Distance travelled by Waterfront Services</td>
<td>24</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>Repainting Cost</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

### Lead Time

- **Phase Number**: 1, 2, 3
- **Lead Time Values**: 0, 5, 10, 15, 20, 25

### Repainting Cost

- **Phase Number**: 1, 2, 3
- **Repainting Cost Values**: 0, 20, 40, 60, 80, 100, 120
Key Benefits Demonstrated During Pilot Sessions

- Reduction in Lead time from phase-1 to phase-3.
- Decrease in repainting cost (Rework).
- On-time completion of repair job.
- Decrease in cycle times due to improved communication and flow.
Value Stream Mapping
Overview of Value Stream Mapping Simulation

- Observe the production of the police patrol boat (using traditional approach) and collect cycle time data.
- Develop the current state map by examining the flow.
- Development of future state map from the current state map using lean tools and techniques.
- Examine the prediction for future state using a computer based simulation model.
- Implement the future state and compare performance metrics.
The Lego Boat and Sub Assemblies

LEGO BOAT

SUBASSEMBLIES

Rear Control  Control Panel  Engine
# Issues in Value Stream Mapping

<table>
<thead>
<tr>
<th>Issues</th>
<th>Lean Tools</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Overproduction</td>
<td>Pull/Kanban</td>
</tr>
<tr>
<td>2 Bottlenecks</td>
<td>Takt time/Line balancing</td>
</tr>
<tr>
<td>3 Transport</td>
<td>Co-location, supermarket</td>
</tr>
<tr>
<td>4 Batch flow/Inventory</td>
<td>Supermarket</td>
</tr>
<tr>
<td>5 Layout</td>
<td>Cellular Manufacturing</td>
</tr>
<tr>
<td>6 Defects</td>
<td>Quality at source</td>
</tr>
<tr>
<td>7 Long lead time</td>
<td>Pull/Single piece flow</td>
</tr>
<tr>
<td>8 Information flow</td>
<td>Pull</td>
</tr>
<tr>
<td>9 Functional layout</td>
<td>Cellular Layout</td>
</tr>
</tbody>
</table>
The division of participants into teams
Room Layout for Phase 1

VSM

Room Layout Phase -1

Supplier → Central Warehouse

Buyer/Planner → Rear Control Assembly

Control Panel Assembly → Engine Assembly

Engine Assembly → Final Assembly

Material flow → Information flow
Results from the Pilot Session -2

- The results differ from session-1, since the times were calculated based on the red-star boat.
- The total cycle time increases from the first phase by 2 mins. but the productivity is higher.
- The productivity went up by 66% in the second phase.

<table>
<thead>
<tr>
<th>PERFORMANCE CRITERIA</th>
<th>PHASE-I</th>
<th>PHASE-II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total # of Employees</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Total Cycle time</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>Total Touch time</td>
<td>4.93</td>
<td>3.07</td>
</tr>
<tr>
<td>No. of Quality Checks</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>Total No. of Boats made</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>No. of boats per minute</td>
<td>0.3</td>
<td>0.5</td>
</tr>
<tr>
<td>Productivity %</td>
<td>30%</td>
<td>50%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TOUCH TIME (min)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Supplier</td>
<td>1.08</td>
<td>1.16</td>
</tr>
<tr>
<td>Central Warehouse</td>
<td>2.01</td>
<td>0.38</td>
</tr>
<tr>
<td>Rear Control Assembly</td>
<td>0.5</td>
<td>0.26</td>
</tr>
<tr>
<td>Control Panel Assembly</td>
<td>0.17</td>
<td>0.15</td>
</tr>
<tr>
<td>Engine Assembly</td>
<td>0.11</td>
<td>0.11</td>
</tr>
<tr>
<td>Final Assembly</td>
<td>1.06</td>
<td>1.01</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CYCLE TIME (min)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Supplier</td>
<td>2.06</td>
<td>2.05</td>
</tr>
<tr>
<td>Central Warehouse</td>
<td>5.24</td>
<td>5</td>
</tr>
<tr>
<td>Rear Control Assembly</td>
<td>2.22</td>
<td>3.3</td>
</tr>
<tr>
<td>Control Panel Assembly</td>
<td>2.12</td>
<td>3.2</td>
</tr>
<tr>
<td>Engine Assembly</td>
<td>1.36</td>
<td>2</td>
</tr>
<tr>
<td>Final Assembly</td>
<td>4.05</td>
<td>2.25</td>
</tr>
</tbody>
</table>
The summary of the results:

1. Additional performance metrics were included as a result of the pilots.
2. The number of boats made in the simulation and the number of boats made per minute were included as performance metrics.
3. The collection of data for the red-star boat helped in identifying cycle time for one boat.
4. Simplification of the processes and forms has resulted in reduced simulation time.
5. The drawing of current state map and future state map are made easier and less complicated by a step by step example.
DESIGN PROCESS SIMULATION KIT
Developed under NSRP Program. ATI Agreement # 2004 323
by Old Dominion University, Northrop Grumman Newport News and Virginia Ship Repair Association Inc.

LIST OF ITEMS IN THE KIT
- Training presentation
- Instructor’s Guide
- Simulation Guide
- Calculators
- Laminated instructions and forms
- Digital clock with remote
- Easel and Chart Paper
- Miscellaneous stationary like, rulers, file folders, permanent markers, cutters, masking tapes, etc
- Kit comes in one large box

DESIGN PROCESS KIT
Cost of the kit: $ 1,600.00

ESTIMATED DELIVERY: 3-4 WEEKS
SUPPLY CHAIN SIMULATION KIT
Developed under NSRP Program. ATI Agreement # 2004 323
by Old Dominion University, Northrop Grumman Newport News and Virginia Ship Repair Association Inc.

SUPPLY CHAIN KIT

ESTIMATED DELIVERY: 6-8 WEEKS

Cost of the kit: $ 4,000.00

LIST OF ITEMS IN THE KIT
- Training presentation
- Instructor’s Guide
- Simulation Guide
- 2 sets of Submarine Models
- Laminated instructions and forms
- Digital clock with remote
- Vernier calipers and rulers
- Variability wheel
  - Miscellaneous stationary like, scissors, file folders, permanent markers, masking tapes, screw drivers, etc
- Kit comes in two large boxes

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- Variability wheel
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SUPPLY CHAIN SIMULATION KIT
Developed under NSRP Program. ATI Agreement # 2004 323
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SUPPLY CHAIN KIT

ESTIMATED DELIVERY: 6-8 WEEKS

Cost of the kit: $ 4,000.00

LIST OF ITEMS IN THE KIT
- Training presentation
- Instructor’s Guide
- Simulation Guide
- 2 sets of Submarine Models
- Laminated instructions and forms
- Digital clock with remote
- Vernier calipers and rulers
- Variability wheel
  - Miscellaneous stationary like, scissors, file folders, permanent markers, masking tapes, screw drivers, etc
- Kit comes in two large boxes
SHIP REPAIR SIMULATION KIT
Developed under NSRP Program. ATI Agreement # 2004 323
by Old Dominion University, Northrop Grumman Newport News and Virginia Ship Repair Association Inc.

Cost of the kit: $ 4,000.00

ESTIMATED DELIVERY: 6-8 WEEKS

LIST OF ITEMS IN THE KIT
- Training presentation
- Instructor’s Guide
- Simulation Guide
- 2 Ship Models
- Laminated instructions and forms
- Digital clock with remote
- Acrylic Dry-dock
- Electric Screwdriver
- Miscellaneous stationary like, scissors, file folders, permanent markers, screw drivers, cutters, body paint, brushes etc
- Kit comes in two large boxes
SCHEDULING SIMULATION KIT

Developed under NSRP Program. ATI Agreement # 2004 323
by Old Dominion University, Northrop Grumman Newport News and Virginia Ship Repair Association Inc.

LIST OF ITEMS IN THE KIT

- Training presentation
- Instructor’s Guide
- Simulation Guide
- 2 Ship Models
- Laminated instructions and forms
- Digital clock with remote
- Acrylic Dry-dock
- Electric Screwdriver
- Variability wheel
  - Miscellaneous stationary like, scissors, file folders, permanent markers, screw drivers, cutters, etc
- Kit comes in two large boxes

ESTIMATED DELIVERY: 6-8 WEEKS

Cost of the kit: $ 4,000.00
Value stream mapping SIMULATION KIT

Developed under NSRP Program. ATI Agreement # 2004 323
by Old Dominion University, Northrop Grumman Newport News and Virginia Ship Repair Association Inc.

List of items in the kit:
- Training presentation
- Instructor’s Guide
- Simulation Guide
- 20 Lego boats
- Laminated instructions and forms
- Digital clock with remote
- Writing pads
- Variability wheel
  - Miscellaneous stationary like, scissors, file folders, permanent markers, masking tapes, etc
- Kit comes in two large boxes

Estimate delivery: 6-8 weeks

Cost of the kit: $ 2,000.00
TRAIN THE TRAINER PROGRAM
Developed under NSRP Program. ATI Agreement # 2004-323
by Old Dominion University, Northrop Grumman Newport News and Virginia Ship Repair Association Inc.

DESIGN PROCESS KIT  SCHEDULING KIT  SHIP REPAIR KIT  SUPPLY CHAIN KIT

Train the Trainer Program

ON-Site - $ 6,400.00
- Two-day training for up to 15 people
- Training in two of the five simulation areas
- Includes travel cost for 1 instructors and 2 assistants

At ODU in Norfolk, VA - $ 3,800.00
- Two-day training for up to 15 people
- Training in two of the five simulation areas

VSM KIT
QUESTIONS ???
For additional information
Please visit the project web site:
http://www.lions.odu.edu/~averma/NSRPindex.htm

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