Lean Aircraft Initiative
Plenary Workshop

Factory Operations Team

October 16, 1996

Presented by:
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MIT
Factory Operation Benchmarking

- Review of benchmarking activities
- Results
- Analysis of data
- Conclusions
- Next steps
- Focus group status report
Benchmarking Objective

Develop comparative benchmarking on member factory flow measures.

Flow Variables:
* Touch Labor
* Cycle Time
* Router Queuing
* Batch Sizes

Support Variables:
* IE Hours
* Part Characteristics
* Distance Traveled
* # of Process Steps
* Process Controls
* Quality
Benchmarking Ground Rules

- Specific parts and data to be collected determined by sector representatives
- Questionnaire based
- Data verification
Metric Definitions

- **Cycle Time (Hours)**
  - The total time from initiation of work order to completion of manufacturing process on work order.

- **Waiting Time (Hours)**
  - Cycle Time - Touch Labor. The time the work order spends on the floor without work being charged to the work order.

- **Router Queuing (Hours)**
  - Time between creation of work order and first process step.
Part Manufacturing Timeline

- Issued to Floor
- First Operation
- Touch Labor
- Work Order Completed

Cycle Time
Router Queuing
Process #1: One Person/Operation per Batch

Process #2: Multiple Persons/Operations per Batch
Flow Efficiency Metric

- Flow Efficiency in principle (Unitless)
  \[ \frac{\text{Fabrication Time}}{\text{Cycle Time}} \]

- Flow Efficiency surrogate (Unitless)
  \[ \frac{\text{Touch Labor/part/crew size}}{\text{Cycle Time} - \text{Router Queuing}} \]
Extruded Sheet Metal Part
- Straight, aluminum
- < 2 ft long
- < 1/4” thick
- “T”, “L”, “C” or “Z” cross section

Brake-Formed Part
- Aluminum
- 2 ft long
- < 1/4” thick

Machined Prismatic Part
- Aluminum
- 3 Axis machine
- < 1 ft³
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Airframe Sector - Extrusions

Note: Bar length is total cycle time

* Estimated router queue times
** Estimated router queue and cycle times

Respondents

Waiting Time
Touch Labor
Router Queue

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Airframe Sector - Brake-formed Parts

- **LEAN AIRCRAFT INITIATIVE**

Bar chart showing data for respondents A, B**, C*, D, E, and G.

- **Waiting Time**
- **Touch Labor**
- **Router Queue**

**Note:** Bar length is total cycle time.

* Estimated router queue times
** Estimated router queue and cycle times

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Airframe Sector - Machined Parts

Note: Bar length is total cycle time

* Estimated router queue times
** Estimated router queue and cycle times
Airframe Sector - Flow Efficiency (Router Queue removed)

Flow Efficiency (touch labor/(cycle time-router queue time))

Maximum
Mean
Median
Minimum
Electronic Sector

- Printed wiring assembly
  - Component insertion through final test
  - Does not include wafer board fabrication

- Electronic Chassis
  - Less chassis fabrication

- Cable / Harness
  - All assembly operations
Electronic Sector - Printed Wiring Assembly

* Based on planned cycle time

NOTE: Bar length is total cycle time
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Electronic Sector - Chassis

* Based on planned cycle time

NOTE: Bar length is total cycle time
Electronic Sector - Flow Efficiency

- Maximum
- Mean
- Median
- Minimum

Adjusted Flow Efficiency

Printed Wire Assemblies

Chassis

Cables/Harnesses
Engine Sector

Three companies responded
Usable data from one company
Results not reported by sector
Used in total data analysis

Items Benchmarked
- Turbine Disk
- Combustor
Summary Observations After Data Collection

- Each respondent’s data collection system was different
- Multiple work methods observed
- Questionnaire method insufficient for gathering detail data
- Few respondents tracked their actual elapsed cycle times
- Work order lot size not the batch size used for processing
Hypotheses
- Higher flow efficiencies with lower lot sizes
- Higher flow efficiencies with shorter distance traveled
- Higher flow efficiencies with fewer process steps

Analysis by sector
- Analysis with all sectors combined
- Influence of process type
- Wait time analysis
Flow Efficiency vs. Lot size (Combined)

Flow Efficiency = 1 / Lot Size
Flow Efficiency vs. Travel Distance (Combined)
Flow Efficiency vs. Process Steps (Combined)
Flow Efficiency = 1 / Lot Size

- **Dedicated Line or Flow Shop**
- **Job Shop**
Factors that influence performance of job shops

- What the facility has optimized
- Operations may be capacity limited
- Machine utilization effect on set up
- Numbers of parts that are processed in this area
- Production environment
Wait Time Components

- Transportation delay
- Lot delay (while all parts are processed)
- Storage delay
## Wait Time Analysis - Airframe Sector

<table>
<thead>
<tr>
<th>Process</th>
<th>Wait Fraction</th>
<th>Lot Delay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extrusion</td>
<td>95%</td>
<td>2%</td>
</tr>
<tr>
<td>Brake Formed</td>
<td>97%</td>
<td>2%</td>
</tr>
<tr>
<td>Machining</td>
<td>94%</td>
<td>3%</td>
</tr>
</tbody>
</table>
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Wait Time Analysis - Electronic Sector

- Could not determine wait times directly
- Bounded the problem
  - Defined maximum wait times
  - Defined I. E. factor necessary to achieve zero wait time
- Process defined one respondent in each type of part that was doing at least twice as good as the other respondents
Dedicated Lines or Flow Shops

Operations Deemed to be a Flow Shop or Dedicated Line

Dedicated Line or Flow Shop Process Efficiencies
Wait Time Analysis

Efficiency versus Travel Distance

- X-axis: Travel Distance
- Y-axis: Efficiency

Data points showing the relationship between efficiency and travel distance.
Wait Time Analysis Conclusions

D Dedicated line or flow shop
   – All wait time in dedicated line or flow shop is waste
   – Transportation delay does not predominate
   – Predominate wait time component is storage delay

Job shop
   – Storage and transportation delay predominate
   – research could not differentiate other contributing factors

Most opportunity for lean improvement is to concentrate on wait time reduction
Cycle Time Reduction

- Gather data to understand wait time
  - part/assembly/product ACTUAL cycle time key
  - part/assembly/product ACTUAL fabrication time
  - Determine wait time and their components
- Analyze causes of wait time
- Implement steps to reduce wait times
- Evaluate results to the production system
- Standardize the improvement across the system
- Reflect on the process and select next effort

Wait Time = Waste
Observations

- Few respondents tracked actual cycle times.
- Router cueing time ranged from 4 to 42% of total cycle time in the airframe sector.
- Wait fraction for airframe sector averages 96%.
- Wait fraction for engine sector averages 87%.
- Could not determine wait times in electronic sector.
  - Comparison of wait time bounds.
  - One electronic sector company showed at least two times better performance.
Conclusions

Wait time reduction = cycle time reduction

- Within sectors apples to apples comparison achieved for each type of part
- Flow efficiency varied inversely with lot size and travel distance
- In job shops storage and transportation delay greater than lot delay times
- For dedicated lines or flow shops the largest component of wait time was storage delay
Next Steps

- Report to respondents
- Application of lessons learned into future research
Focus on LEM overarching practice - Identify and Optimize Enterprise Flow

Concentrate on factors that effect “Order to point of use delivery cycle time”

Use LEM to classify results

Focus Group Identified field research site

Data collection methodology developed at MIT

Site introductory visit completed

Data collection to commence next week