

Lean Aerospace Initiative

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Policy Rules for Virtual Real-Time Scheduling and Integration of Production Operations with Suppliers

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Goals of Talk

- To describe a factory scheduling policy.
- To suggest that some of its features are of interest to supply chain management:
  - ⋆ responsiveness to events,
  - ⋆ real-time global information distribution and utilization,
  - ⋆ real-time local information utilization.

Outline

- What is a Factory Scheduling Policy?
- Description of Policy
  - ⋆ Structure
  - ⋆ Assumptions
  - ⋆ Definitions
  - ⋆ Policy Statement
- Implementation Experience
- Implications for the Supply Chain

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Scheduling Policies

- *Scheduling Policy:* a set of rules for allocating production resources in real time.

- *Performance:* A good policy will
  - ⋆ react appropriately to random events;
  - ⋆ take into account finite capacity, setup costs, etc.

- *Usability:* A policy must be
  - ⋆ easy to implement;
  - ⋆ easy to interact with;
  - ⋆ quick to respond.

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Experiment

- Goal: to determine if the policy that we have developed is effective and useful.

- Laboratory: Boeing Portland 777 Flap Support Business Unit.

- Activities: We have been working in cooperation with Boeing personnel to implement the policy. When it is up and running for a few months, we will compare its performance to the factory's prior performance.

- This is *not* a consulting activity, and we are *not* getting any financial support from Boeing.

- The prior scheduling system was manual and informal.

Policy Goals

- to produce good performance (production rate, lead time, etc.);
- to provide a clear and simple strategy for normal factory operations;
- to provide a clear and simple strategy to get out of a crisis;
- to produce *easily predictable* performance.
  - ⋆ It will eventually be possible to estimate the performance of the policy by numerical/analytical techniques *instead of* by simulation. Such methods are fast and can be used for factory design and optimization.

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Background

- Deterministic scheduling found inadequate because of random events.
- Simple rules (FIFO, EDD, etc.) found to be simplistic.
- CONWIP beats kanban.
  - ⋆ CONWIP: constant work in process. Load a part only when a part leaves the system. Information is sent to the upstream end of the process.
  - ⋆ kanban: pure pull with finite buffers. Information sent to the immediate upstream neighbor.
- Hybrid CONWIP beats CONWIP.
  - ⋆ Hybrid CONWIP: CONWIP with finite buffers. Mixture of local and global information flow.
- Release is more important than local rules.
  - ⋆ Release: letting material into the system.

Policy Concept

- There are a set of *control points* that limit the flow of material into the system.

- There are *two* limits on flow at each control point: finite buffers, and how far production is ahead of demand.

- At each control point, the policy resequences the material. That is, material may have been produced in less than ideal order upstream because of machine failures or other disruptions. At each control point, the parts are resequenced in order of priority and lateness.

- The finite buffers and the resequencing also serve to prevent the propagation of disruptions.

Policy Structure

- preparation activities
  - ⋆ in principle, performed only once
  - ⋆ *(in reality, performed after major persistent changes)*

- real-time activities — performed frequently
  - ⋆ in principle, every time an important event occurs
  - ⋆ *(in practice, can be performed less often)*

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Assumptions

- adequate (but finite) capacity
- unreliable machines, or other disruptions
  - ⋆ ... with exponentially distributed up- and down-times.
- multiple part types following a handful of similar paths
  - ⋆ not a totally general job shop
- finite, homogeneous buffers
- static priority ranking
- due dates for products
- setups and yield ignored
  - ⋆ *... in the preliminary formulations. These will be added later.*
- batching permitted, with policy extension

Definitions — 1

- A *control point* is a machine or resource where we apply the policy fully.
  - ⋆ At all other resources, use a simpler policy (eg, FIFO).

- A *hedging time* is the time that we allow a part between a control point and the end of the process (ie, the shipping dock).
  - ⋆ a conservative estimate of the lead time that takes into account the possibilities of delay due to machine failure and queuing; and takes into account the risk of late deliveries and the cost of inventory.
  - ⋆ *NOT* the expected lead time.
  - ⋆ greater than the minimal time for remaining process.

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Definitions — 2

- A resource is *available* if it is not performing an operation, not undergoing repair, and not otherwise occupied.
- A part is *available* at a control point if it is present and has had the previous operation, and if it is not blocked downstream.
  - ⋆ If buffers are infinite (ie, if there are no internal limits on inventory), then a part is available if it is there.
- A part is *ready* at a control point if it is available and

$$\boxed{\text{the current time} + \text{the hedging time} > \text{the due date.}}$$

  - ⋆ At Machine X (a control point), the hedging time for Type Y parts is 20 days and 3 hours. If the current time is 11:00 AM on July 1, a Type Y part is ready if its due date is earlier than 2:00 PM on July 21.

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The Policy (Preparation Phase)

- In advance,
  - ⋆ select control points
  - ⋆ rank order the parts
  - ⋆ determine hedging times from each control point to the end of the process for each part type.
  - ⋆ determine buffer sizes.

The Policy (Real Time Phase)

Non-Batch Machine

- In real time,
  - ⋆ at each control point, whenever the resource becomes available,
    - ∗ Find the highest ranking part type that is ready. Load it and work on it immediately.
    - ∗ If no available parts are ready, wait. Look at the system again when either another part arrives from upstream or one of the available parts becomes ready, whichever comes first. Then go to the previous step.
  - ⋆ at each other resource, do something simple like first-in-first-out. Do not allow the resource to be idle when there are parts that can be worked on.

Batch Machine

- *Definition:* A batch machine does many parts at the same time. The parts need not be of the same type, but they must be compatible.
- *Example:* Shot peen.
- *Issue:* If many parts, but no full batch, are present, capacity may be wasted if we load a partial batch or wait for a full batch. Time and even more capacity is wasted if we wait for a full batch of ready parts.

The Policy (Real Time Phase)

Batch Machine at a Control Point

- In real time, whenever the machine becomes available:
  - ⋆ Form *logical batches* — sets of waiting parts that are compatible. (The batches include all waiting parts, not just those that are ready.)
  - ⋆ Load the batch that contains the highest ranking part that is ready. (Non-ready parts will be processed along with ready parts.)
  - ⋆ When the operation is complete,
    - ∗ advance all the ready parts;
    - ∗ hold all the non-ready parts until they are ready, and then advance them.

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Behavior and Characteristics

- There are *two* mechanisms for maintaining order: the limited buffer sizes, and the hedging times. Together, they ensure that
  - ⋆ material advances in an orderly fashion; and
  - ⋆ inventory is limited.
- A machine will not be idle unless
  - ⋆ no material is waiting, or
  - ⋆ all parts that are waiting are blocked (ie, the buffers that they would be sent to are full), or
  - ⋆ all parts that are waiting and are not blocked are too early.
- If the selected hedging times are too long, excess inventory; if too short, frequent stockouts.
- Eventually, we will provide efficient ways of calculating the hedging times. Until then, use reasonable educated guesses.

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Decomposition

1. Hedging times are related to hedging points — desirable local surpluses.
2. A hedging point strategy can be expressed as the operation of a network of assembly and disassembly machines and finite buffers. Some portions of the network have material; others have *tokens*.
3. Current research is aimed at extending decomposition methods to these networks:
   - Decomposition methods approximately analyze systems with finite buffers.
   - Existing methods work very well for tree-structured assembly/disassembly networks with a single part type.
   - Optimization methods work very efficiently for these systems.
   - Very recent results found for two-part type tandem systems.
   - Methods exist for single-part, single-loop systems, but must be improved and extended.

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Related Policies

Most similar policies do not have a mechanism for calculating hedging times (called *lead times*, *slack times*, or other terms).

Most similar policies have no analytic means of predicting performance, or for determining estimated lead times.

In addition,

- *MRP* allows a variety of different policies for short-term scheduling.
- *Least Slack* does not rank parts, and does not allow a machine at a control point to be idle even if it is very far ahead of demand.
- *Drum-Buffer-Rope* is a CONWIP-like policy emphasizing bottleneck utilization.

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Implementation and Experience

- Boeing, Portland, Oregon.
- Implementation interrupted by reorganization.
- Qualitative observations on performance:
  - ⋆ Factory appears to be operating more smoothly than before.
  - ⋆ The policy helped them recover from a crisis.
  - ⋆ They are keeping our policy operating after the reorganization.
  - ⋆ They invited us back to continue observing, and to adjust it to reduce inventory.
- Usability:
  - ⋆ They did the software, not us. They built on an existing MRP system, and made no major changes.
  - ⋆ No complaints.

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Implications for the Supply Chain

- Good performance obtained because demand information is immediately distributed to all stages of the process.

- Policy provides a framework for lead time and inventory reduction.

- *Adaptation:* Since demand information may not be available early enough for the upstream stages, forecast information will be needed.

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Current Research

- Simulation is being developed.
- Decomposition methods are being extended.
- Operational methods for setups are being considered.
- Experiments are being conducted and initiated.