

NSF Engineering Research Center for

Reconfigurable Manufacturing Systems



A Framework for Evaluating Production Policies to Improve Customer Responsiveness

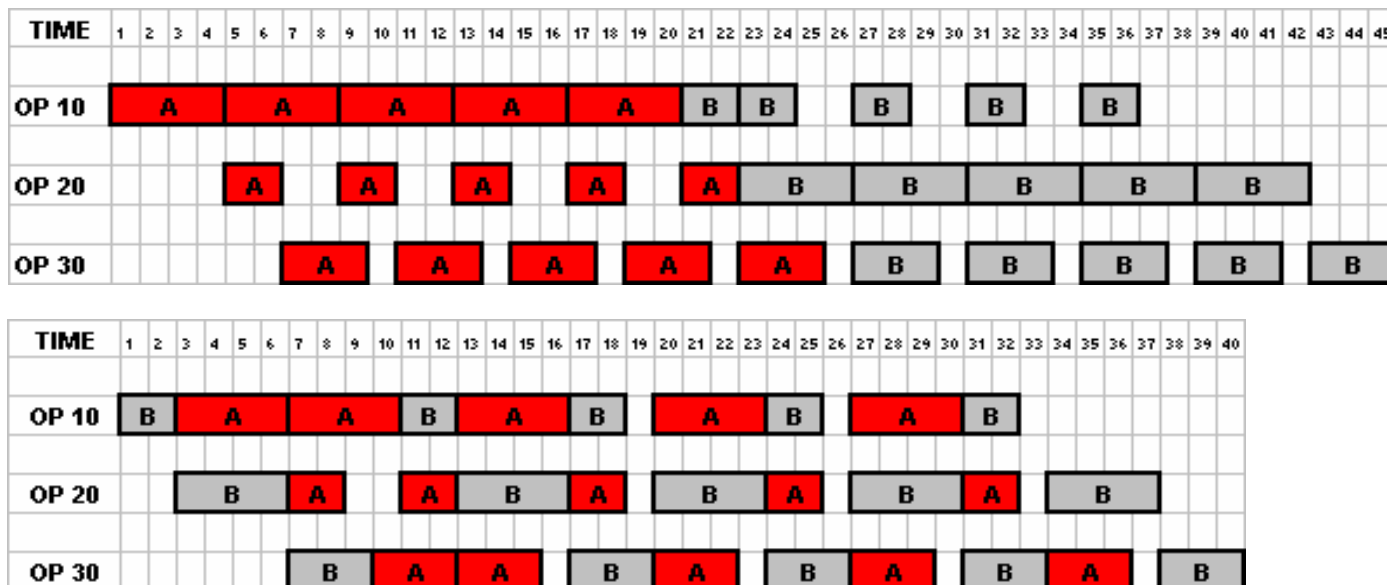
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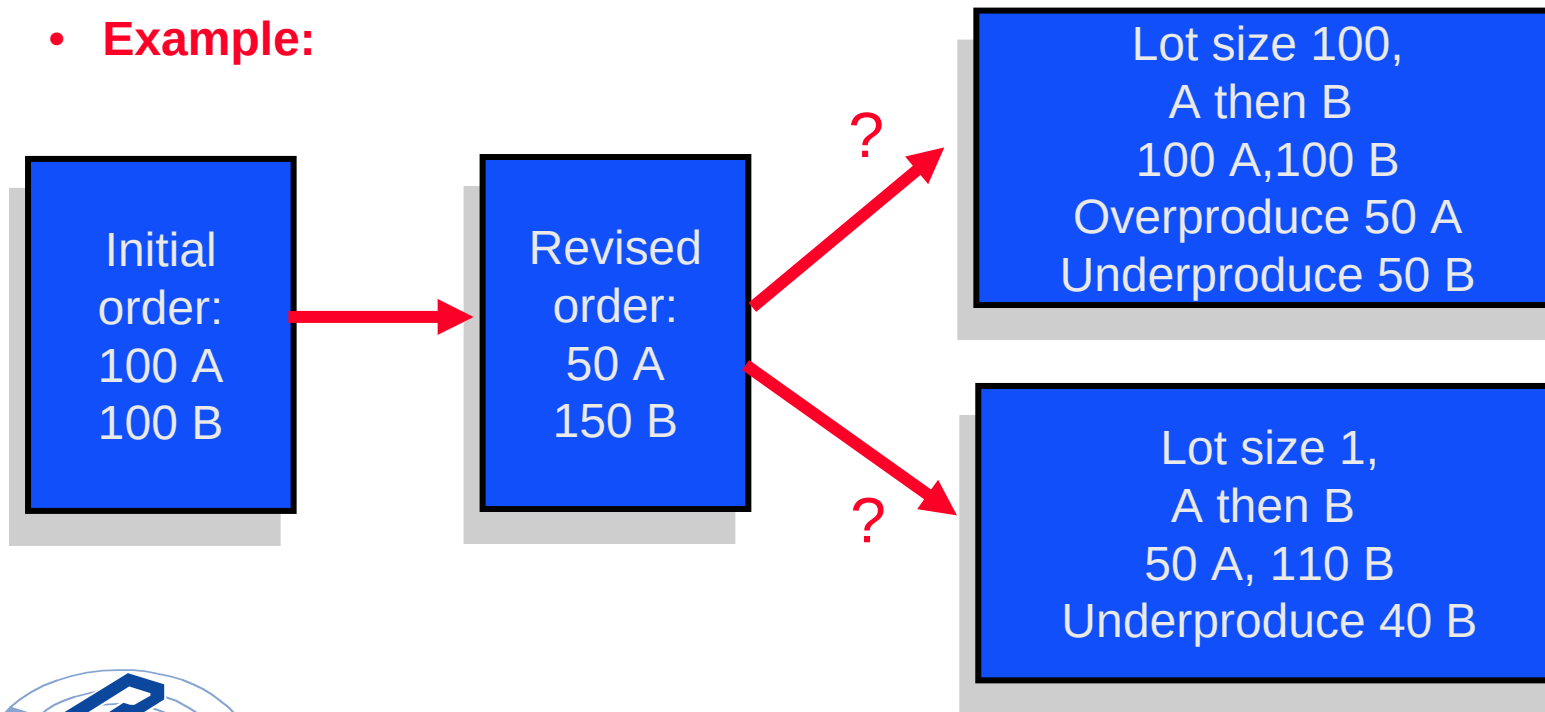
Project Background

- Initial efforts: Optimization of product sequencing in a flow shop environment
 - Simple case as baseline for more complex production environments
 - Parallel machine lines, crossovers, etc.
- Example



Project Motivation

- What happens when disruptions occur?
 - Machine failures
 - Customer order changes (after production has begun)
- “Optimal” sequences may not be very robust
- Example:



New Project Definition

- **How should we sequence products in a flow shop environment subject to internal and external disruptions?**
 - Machine failures
 - Customer order changes
- **Possible objectives:**
 - Minimize average makespan
 - Minimize average makespan subject to constraint on variance
 - Maximize probability of meeting all due dates
 - Minimize probability of failing to satisfy most important customer's demand
- **Key challenge 1: Different users will have different objectives!**
- **Key challenge 2: Computational challenges of stochastic optimization**



Analytical Framework

- **Focus on developing a framework for analyzing different *policies*:**
 - Initial sequence
 - Rules dictating how that sequence should be modified when disruptions occur
- **Importance of flexibility:**
 - System configurations
 - Probability distributions for disruptions
 - Performance metrics
- **Descriptive rather than prescriptive**
 - What-if scenarios
 - Fundamental insights
 - Optimization as in imbedded tool



Framework Inputs

- **System configuration**
 - Flow shop (pure serial line)
 - P products
 - M machines
 - Product p spends time $t[p,m]$ on machine m
 - No buffer (can easily be relaxed)
- **Customer inputs**
 - C customers
 - Customer c demands $u[p,c]$ units of product p at due date $d[p,c]$
- **Disruption data**
 - Distributions for machine failures (time to failure, time to repair)
 - Distributions for customer order changes (change in quantity, change in due date)



Policy Components

- A *policy* is not just an *initial* sequencing plan, but a *strategy* for modifying this plan in response to disruptions
- Three components are used to define a policy:
 - Sequencing rules
 - Update triggers
 - Demand modification strategies
- Example
 - Begin by sequencing product A, then B, then C in lots of size 10
 - At $T/2$, update demand with any customer order changes, then schedule remaining demand in lots of size (remaining demand / 2)



Policy Components, cont.

- **Modular framework**
 - Add new components as the system grows
 - Combine these components in many different ways to form and assess new policies
- **Sample sequencing rules**
 - Optimal makespan
 - Fixed lot size
 - Proportional production
- **Sample update triggers**
 - Event-driven
 - Time-driven
- **Sample demand modification**
 - Sequence $p\%$ of all customer demands
 - Sequence according to customer-specific demand change history



Simulation

- **Discrete event driven simulation**
- **Implementation:**
 - **User specifies inputs:**
 - » **System configuration**
 - » **Demands**
 - » **Disruption distributions**
 - **User specifies policy:**
 - » **Initial sequencing rule**
 - » **Update triggers and resequencing rules**
 - » **Demand modification strategy**
 - **User-specified number of “scenarios” or “instances” are generated, based on random realizations of the probability distributions**
 - **Policy is applied to each of these scenarios and statistics are gathered**
 - **Implemented in C++ with ongoing enhancements to component set**



Metrics

- **Makespan (i.e. time to completion)**
- **Costs**
 - Production
 - Holding
 - Shortage
- **Failures to make due date**
 - Quantity unavailable at due date
 - Delay time until completion
- **Customer responsiveness curve**
- **For most metrics, multiple statistics**
 - Mean, variance, minimum, maximum...



Example – Hypothesis

- **Hypothesis:**

Given a mix of products which are fairly balanced (but imbalanced across products) and a fixed lot size policy, we should prefer:

- large lot sizes (to decrease bottlenecks)
- frequent updates (to avoid overproduction)



Example – Problem Characteristics

Products	Stage 1 Time Units	Stage 2 Time Units	Stage 3 Time Units	Total Demand
A	10	9	11	100
B	2	3	4	110
C	8	7	7	95

Product Descriptions

Customer A		Customer B		Customer C	
P	%	P	%	P	%
0.97	0	0.97	0	0.99	0
0.015	- 2.5	0.01	+ 25	0.005	+ 25
0.015	+ 2.5	0.01	- 25	0.005	- 50
		0.005	+ 10		
		0.005	- 10		

Demand Disruption Distributions



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Example – Problem Characteristics

Machine	MTTF Time Units	MTTR Time Units
1	U (70,110)	U (5,15)
2	U (150,300)	U (20,40)
3	U (125,175)	U (1,4)

Machine Failure Distributions

- Instantaneous changeover
- $T = 3000$

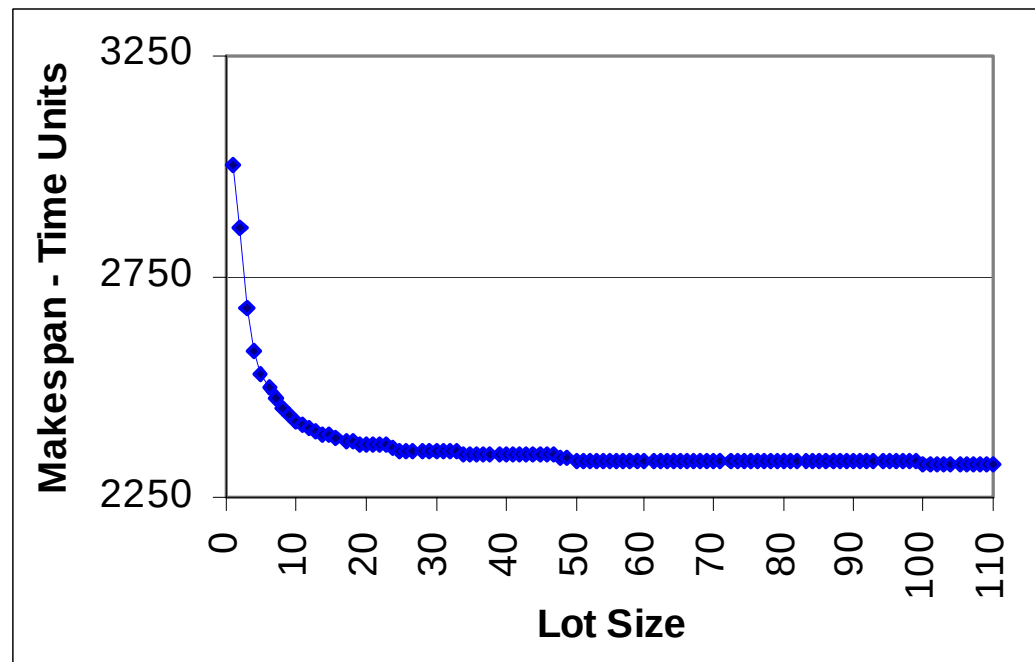


Example – Policy

- Our policy uses fixed lot size sequencing, with product ordering A, B, C
- We assume fixed-interval updates
 - Demand is modified
 - Outstanding demand is rescheduled from current existing lot
- Experiment 1: Lot size vs makespan
 - Fully deterministic
 - How does makespan vary as lot sizes varies



Example – Experiment 1



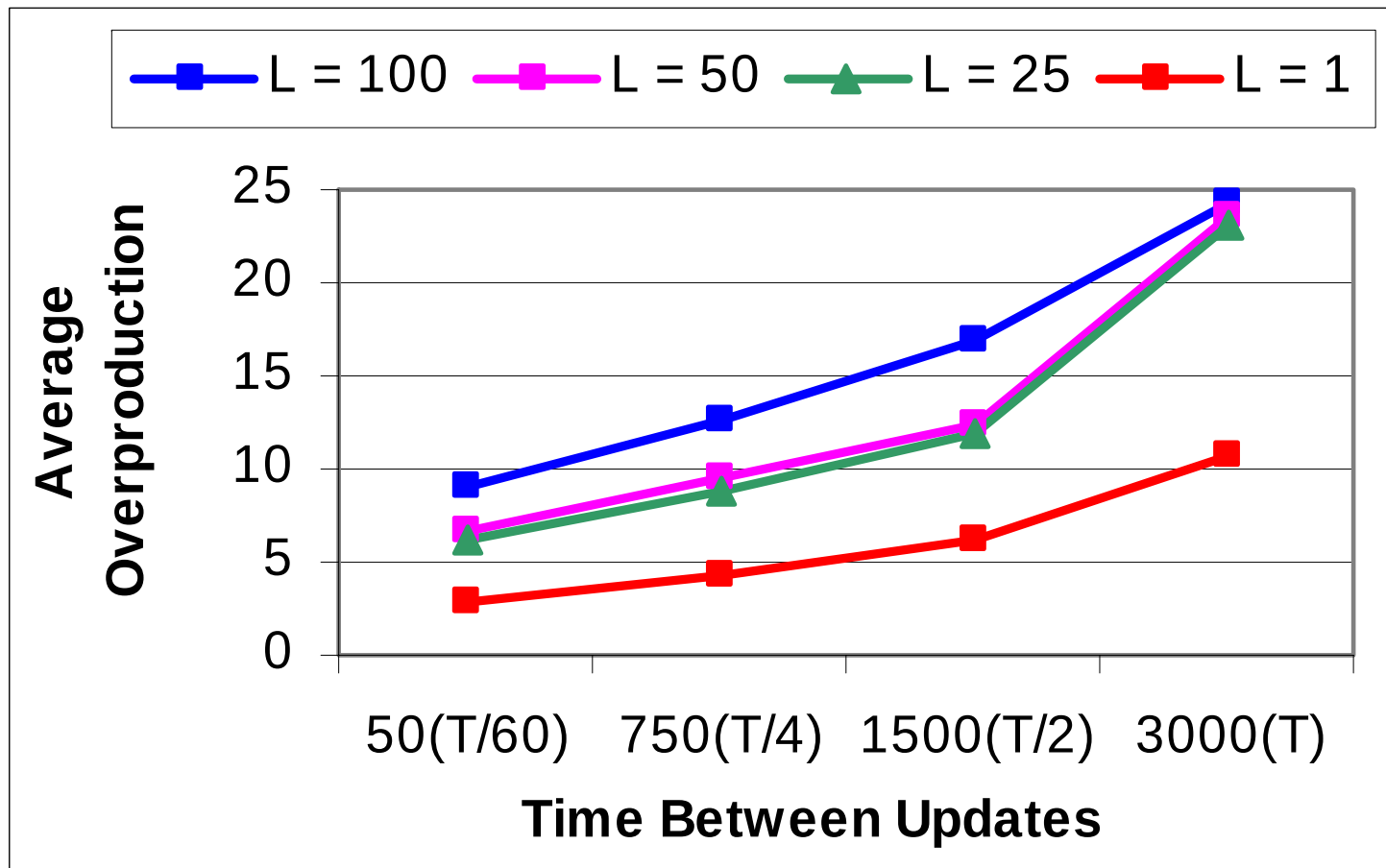
Lot size 70: 70 A 70 B 70 C 30 A 40 B 25 C

Lot size 71: 71 A 71 B 71 C 29 A 39 B 24 C

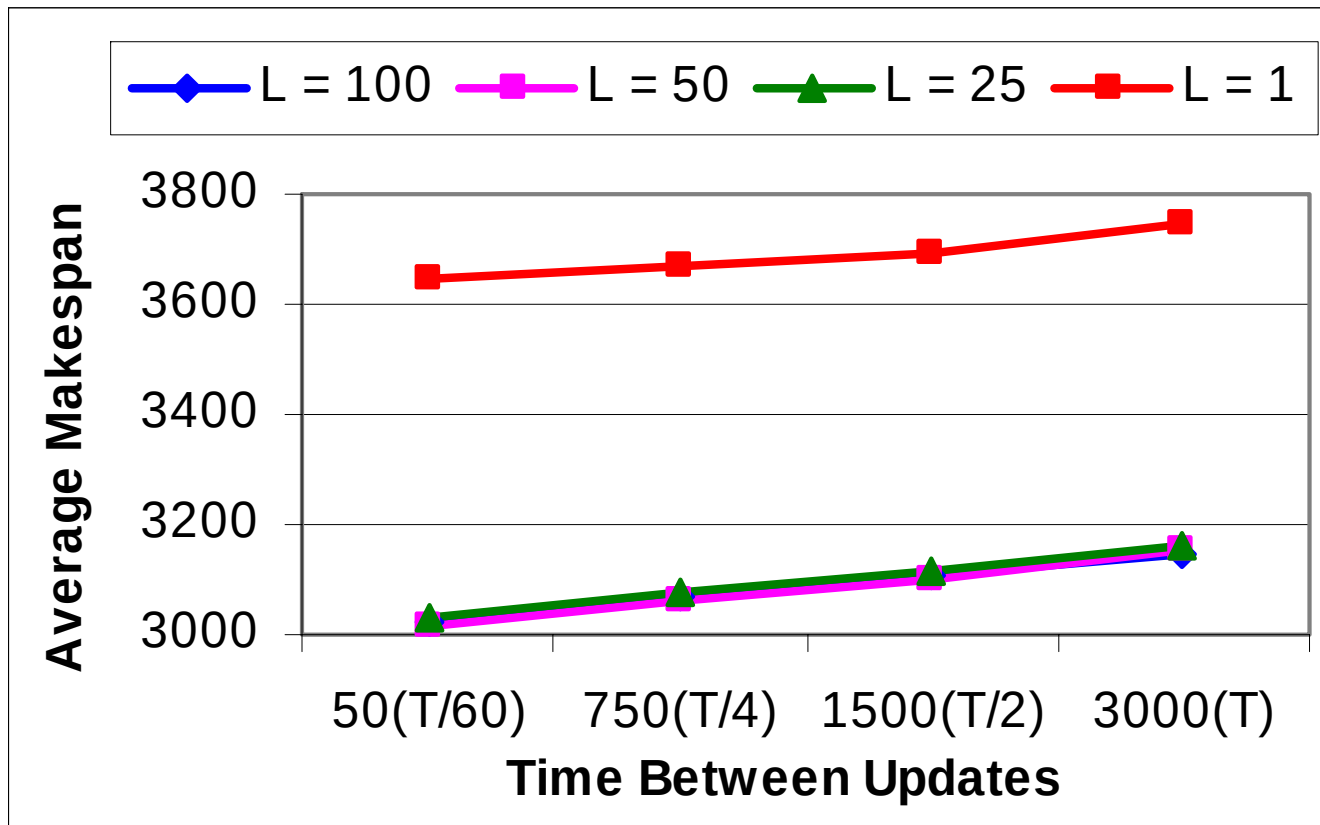


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Example – Experiment 2



Example – Experiment 2, cont.



Current Status

- **C++ implementation of basic functionality completed**
 - Limited set of sequencing rules, update triggers, disruption distributions, etc.
- **Continually expanding functionality**
 - Changeover times and costs
 - Buffers
 - Cost-based metrics
- **Larger-scale changes:**
 - Other manufacturing environments
- **Publication to appear in transactions from this summer's CIRP conference**
- **Feedback welcome!!!**

