Preventive Maintenance Principles
SPL 7.2

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Overview

- Learning Objectives
  - Familiarity with the different types of maintenance activities
  - Appreciation of the benefits of preventive maintenance
  - Understanding of lean principles for designing a preventive maintenance schedule
  - Awareness of specific challenges to implementing preventive maintenance
- Session Design (20-30 min.)
  - ***Part I:*** *Introduction and Learning Objectives (1-2 min.)*
  - ***Part II:*** *Key Concept or Principle Defined and Explained (3-5 min.)*
  - ***Part III:*** *Exercise or Activity Based on Field Data that Illustrates the Concept or Principle (7-10 min.)*
  - ***Part IV:*** *Common "Disconnects," Relevant Measures of Success, and Potential Action Assignment(s) to Apply Lessons Learned (7-10 min.)*
  - ***Part V:*** *Evaluation and Concluding Comments (2-3 min.)*

Types of Maintenance

- Breakdown Maintenance:
  - Waiting until equipment fails before repairing or servicing it
- Preventive Maintenance (PM):
  - (Time-based or run-based) Periodically inspecting, servicing, cleaning, or replacing parts to prevent sudden failure
  - (Predictive) On-line monitoring of equipment in order to use important/expensive parts to the limit of their serviceable life
- Corrective or Predictive Maintenance:
  - Improving equipment and its components so that preventive maintenance can be carried out reliably

Benefits of Preventive Maintenance

- *"…the cost of breakdown maintenance is usually much greater than preventive maintenance."* [1]
- Preventive maintenance…
  - Keeps equipment in good condition to prevent large problems
  - Extends the useful life of equipment
  - Finds small problems before they become big ones
  - Is an excellent training tool for technicians
  - Helps eliminate rework/scrap and reduces process variability
  - Keeps equipment safer
  - Parts stocking levels can be optimized
  - Greatly reduces unplanned downtime

[1] *http://www.prenhall.com/divisions/bp/app/russellcd/PROTECT/CHAPTERS/CHAP15/HEAD01.HTM*

The Manufacturing Game

- Similar to the Beer Game
- Simulates a typical plant with three roles:
  - Operations Manager
  - Maintenance Manager
  - Spare Parts Stores Manager
- Each round, participants make decisions such as:
  - Which equipment to take down for PMs
  - How to allocate maintenance resources
  - How many spare parts to order
- Revenue, cost, output, uptime, inventory are recorded

Source: Business Dynamics: Systems Thinking and Modeling for a Complex World, Sterman, John D., 2000.

The Manufacturing Game Results

- Teams who follow a cost-minimization strategy (reactive maintenance policies) are able to keep costs low for a while. However, as defects build up they find their uptime falling and costs rising.
- Teams who follow a preventive maintenance strategy initially find higher costs and reduced uptime as equipment is taken offline for planned maintenance. Soon, however, these teams begin to greatly outperform teams following a cost-minimization strategy.

Source: Business Dynamics: Systems Thinking and Modeling for a Complex World, Sterman, John D., 2000.

When Does PM Make Sense?

- PM makes sense when the cost of doing PM is less than the cost of NOT doing PM.

$$\text{PM makes sense if } C_{DoingPM} < C_{NotDoingPM}$$

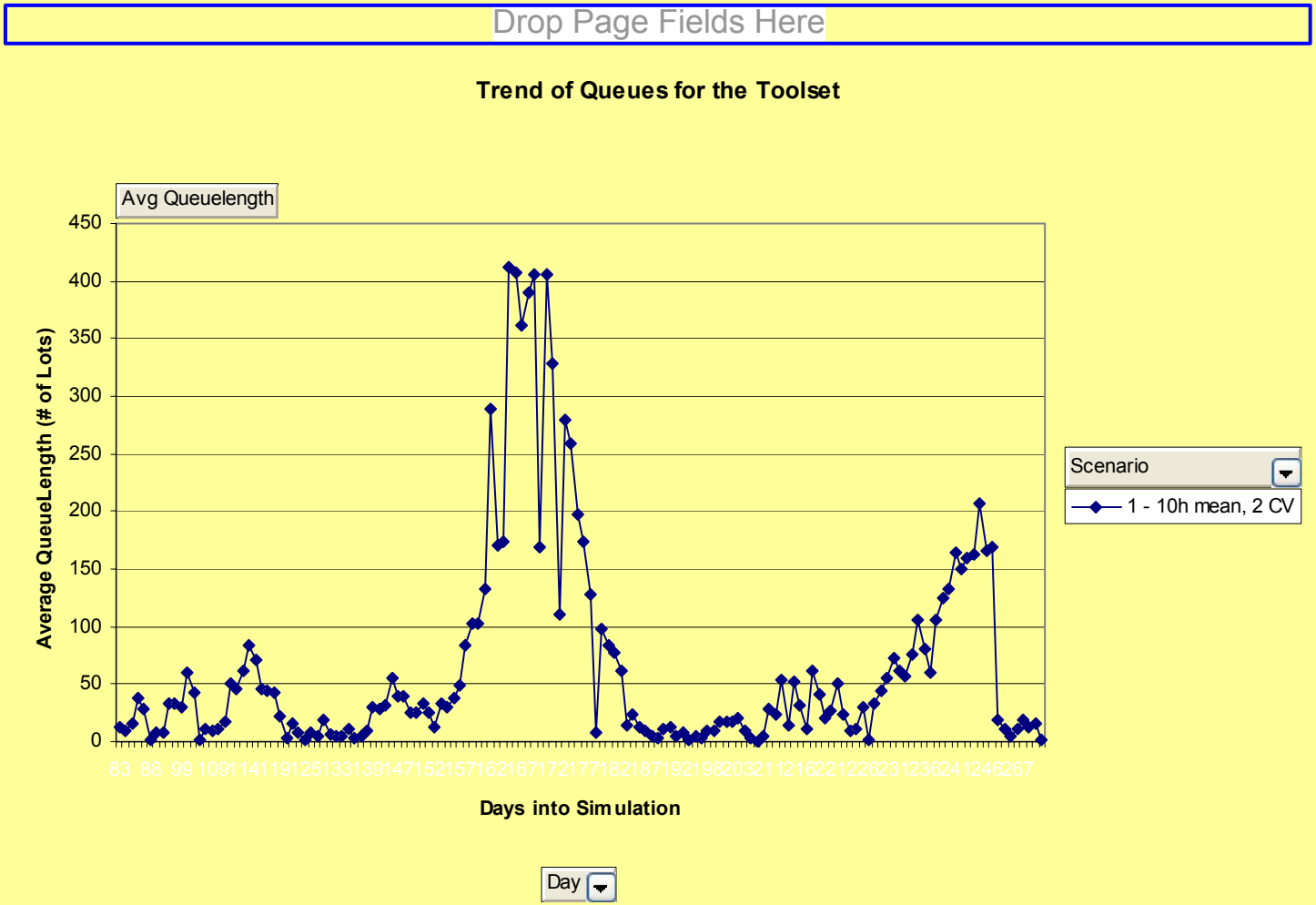
  - $C_{DoingPM}$ = f(hours of not running equipment, loss in employee morale from doing PM instead of "real work", materials and man-hours consumed in PM, potential for making things worse, etc.)
  - $C_{NotDoingPM}$ = f(cost of losing/reworking a failed batch (unless PM makes no difference in preventing the failure), materials and man-hours spent repairing equipment, loss of equipment lifetime, loss in employee morale from NOT doing PM, reduced employee familiarity with equipment, etc.)

Optimizing a PM Schedule

- Question:
  - If a certain piece of production equipment requires ~10 hours of preventive maintenance per week, how should those 10 hours be scheduled?
- Answer:
  - In a 24x7 manufacturing operation, it is typically better to perform the ~10 hours of activities in several smaller periods of time, for instance 5 PM activities that take ~2 hours each
  - Duration and variability in preventive maintenance are key factors in whether equipment will be able to maintain a steady flow of output

PM Durations: Simulation 1

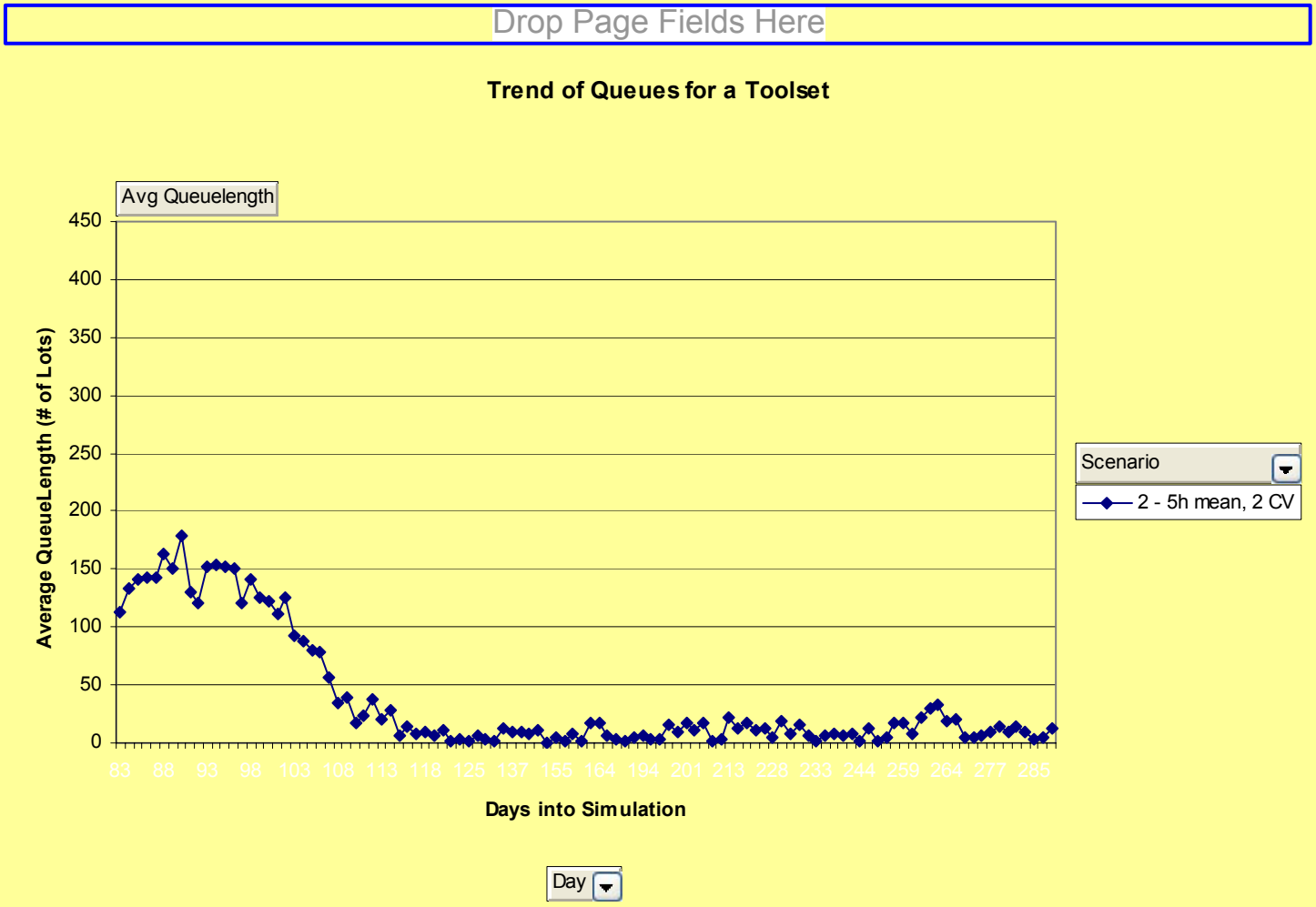
- Simulation of equipment with a 10 hour average PM duration, std dev 20 hours (85% availability)



Data from a simulation run at Intel Fab 11X.

PM Durations: Simulation 2

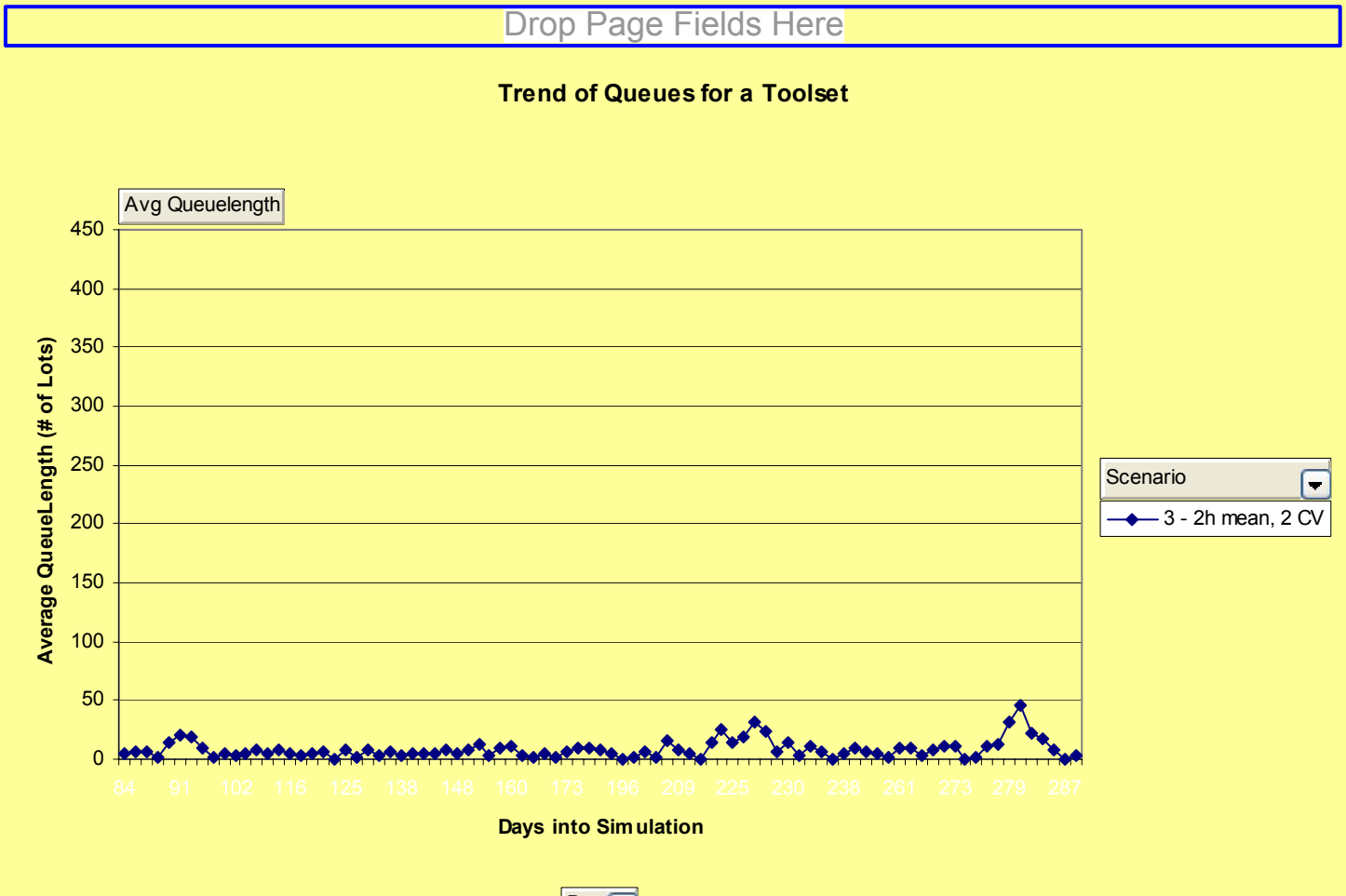
- Simulation of equipment with a 5 hour average PM duration, std dev 10 hours (85% availability)



Data from a simulation run at Intel Fab 11X.

PM Durations: Simulation 3

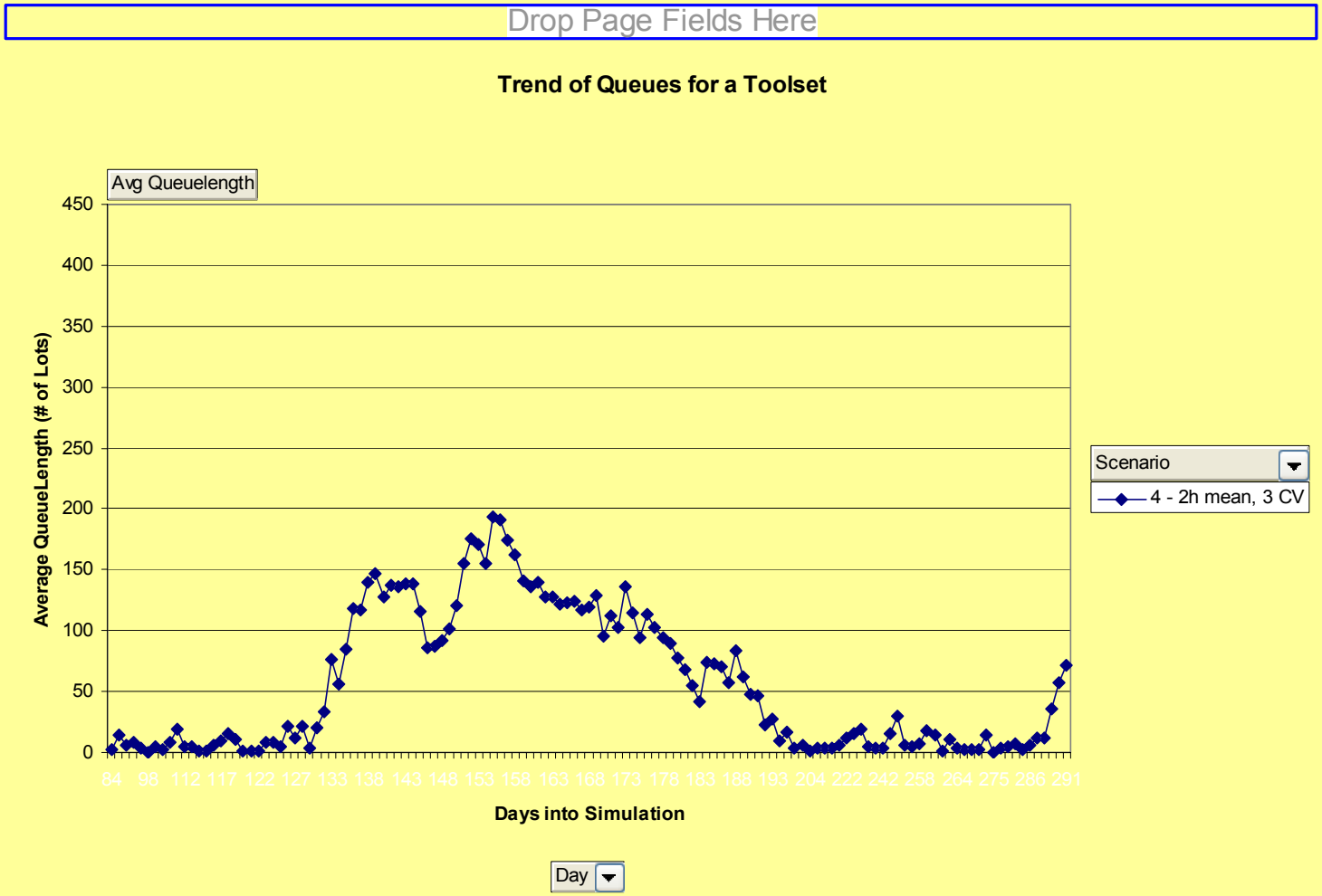
- Simulation of equipment with a 2 hour average PM duration, std dev 4 hours (85% availability)



Data from a simulation run at Intel Fab 11X.

PM Durations: Simulation 4

- Simulation of equipment with a 2 hour average PM duration, std dev 6 hours (85% availability)



Data from a simulation run at Intel Fab 11X.

PM Durations: Why they matter

- For the exact same availability on a piece of equipment:

Simulation	Avg QueueLength	StdDev QueueLength
1) μ=10h, σ=20h	56	63
2) μ=5h, σ=10h	38	52
3) μ=2h, σ=4h	8	8
4) μ=2h, σ=6h	56	57

- Shorter PM durations mean a difference in days of lot cycle time!
  - Each day of factory cycle time = millions of $$
- Regardless of the mean, performing PMs inconsistently is functionally equivalent to consistently having much longer downtime durations

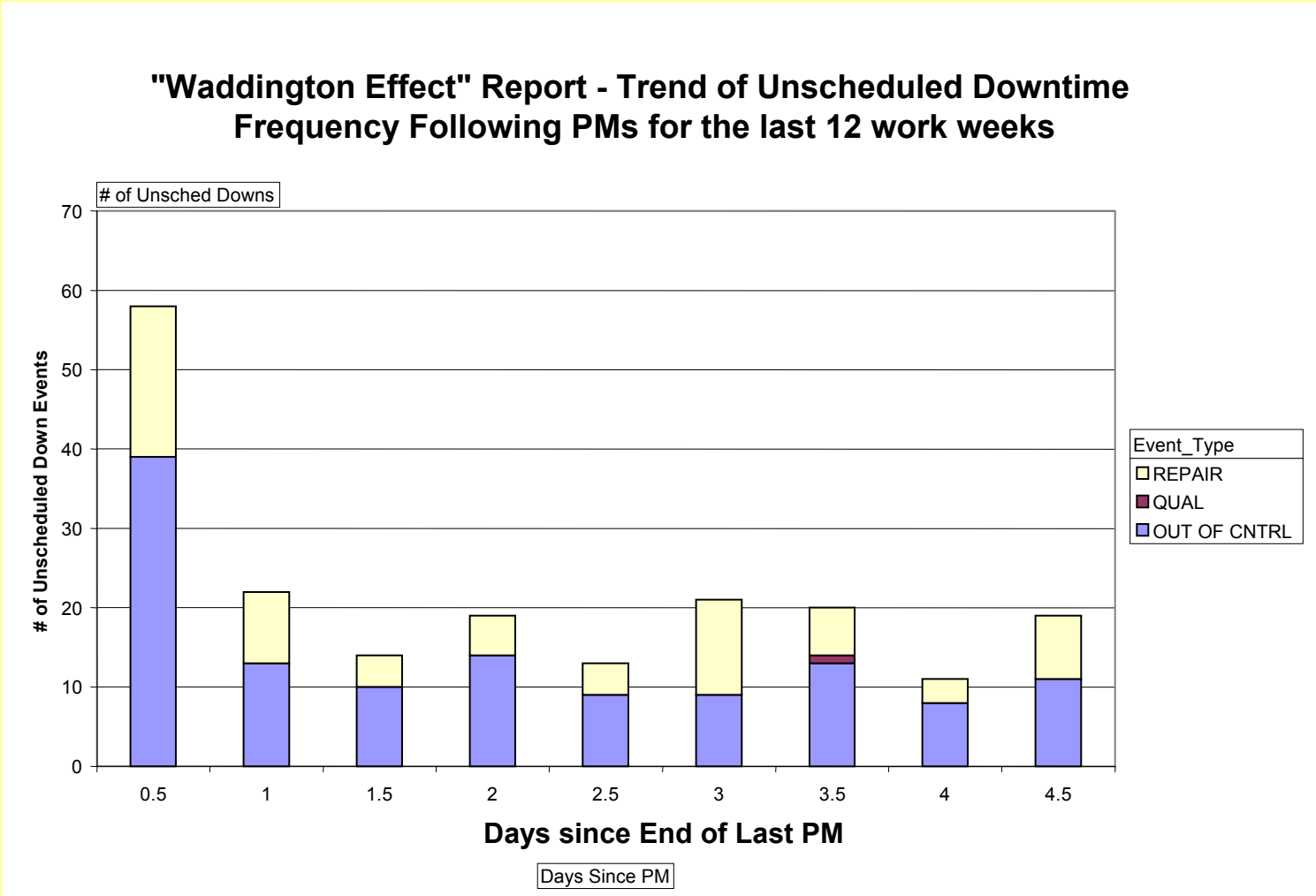
Data from simulations run at Intel Fab 11X.

The "Waddington Effect"

- First observed by C.H. Waddington during WWII for British aircraft maintenance
- Background theory: unscheduled downtime should be a random phenomenon
- If all unscheduled downtime events are plotted with respect to the last PM, there should not be any pattern evident
- A pattern of increased unscheduled downtime immediately following PM's is a "Waddington Effect"

Information from a presentation given at Intel Fab 11X.

The “Waddington Effect”



- Impact of Waddington Effect = 1.4% Availability

Data from a set of production tools at Intel Fab 11X.

Challenges to Implementing Preventive Maintenance

- **Social Factors**
  - Organizations are frequently structured in ways that promote local optimums (cost, shiftly output goals, etc.)
  - The benefits of preventive maintenance are not always well understood
  - The focus on minimizing maintenance costs has to shift to maximizing overall organizational performance
- **Technical Factors**
  - Breakdown maintenance is typically cheaper than preventive maintenance in the short-term
  - Under-trained technicians can cause more damage than they prevent

Concluding Comments

- Performing preventive maintenance is almost always the best long-term strategy to maintain equipment
- PM scheduling and strategy are keys to maximizing output while reducing work-in-process inventory
- Due to short-term cost increases and local optimums, there are barriers to implementing a preventive maintenance strategy at some plants

Appendix: Instructor's Comments and Class Discussion for 7.2

- PM is an important tool for establishing stability necessary for other lean elements:
  - Andon, 5s, etc.
- How do you escape the crisis management whirlpool?
  - Social disconnects:
    - Change the mindset of management, maintenance group from reaction to prevention
    - May need to be done in steps

Appendix: Instructor's Guide

Slide	*Time*	*Topic*	*Additional Talking Points*
1-3	2-3 min	Introduction, overview and learning objectives	• Acknowledge contributors to the presentation • Provide an overview of the learning objectives
4-5	3-5 min	Key Concepts	• Describe the 3 types of maintenance • Explain the benefits of preventive maintenance
6-15	7-15 min	Exercises/Activities	• Go through the key learnings of the Manufacturing Game • Go through a PM optimization example • Discuss "Waddington Effect"
16	2-3 min	Disconnects	• Discuss the difficulties of implementing preventive maintenance in a reactive maintenance culture
17	1-2 min	Concluding comments	• Summarize key points of preventive maintenance