Machining Operations-
Cycle Time
Module 8.2

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Presentation for:
ESD.60 – Lean/Six Sigma Systems
MIT Leaders for Manufacturing Program (LFM)
Summer 2004

These materials were developed as part of MIT's ESD.60 course on "Lean/Six Sigma Systems." In some cases, the materials were produced by the lead instructor, Joel Cutcher-Gershenfeld, and in some cases by student teams working with LFM alumni/ae. Where the materials were developed by student teams, additional inputs from the faculty and from the technical instructor, Chris Musso, are reflected in some of the text or in an appendix

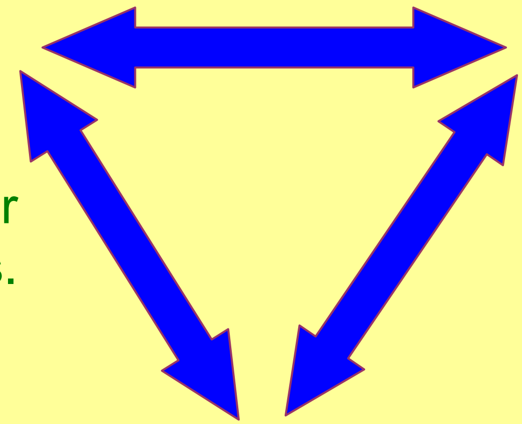
Overview

- Learning Objectives
  - Impact of cycle time on machining operations
  - The cycle time metric, a key indicator of process and equipment performance
  - How cycle time differs from takt time
  - Methods for controlling cycle time.

- 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.)*

Cycle Time as Process *Cash Flow*

Just as cash flow is a direct measure of company financial performance, cycle time is a direct measure of process and equipment performance.



Cycle Time

The time to complete a task or collection of tasks.

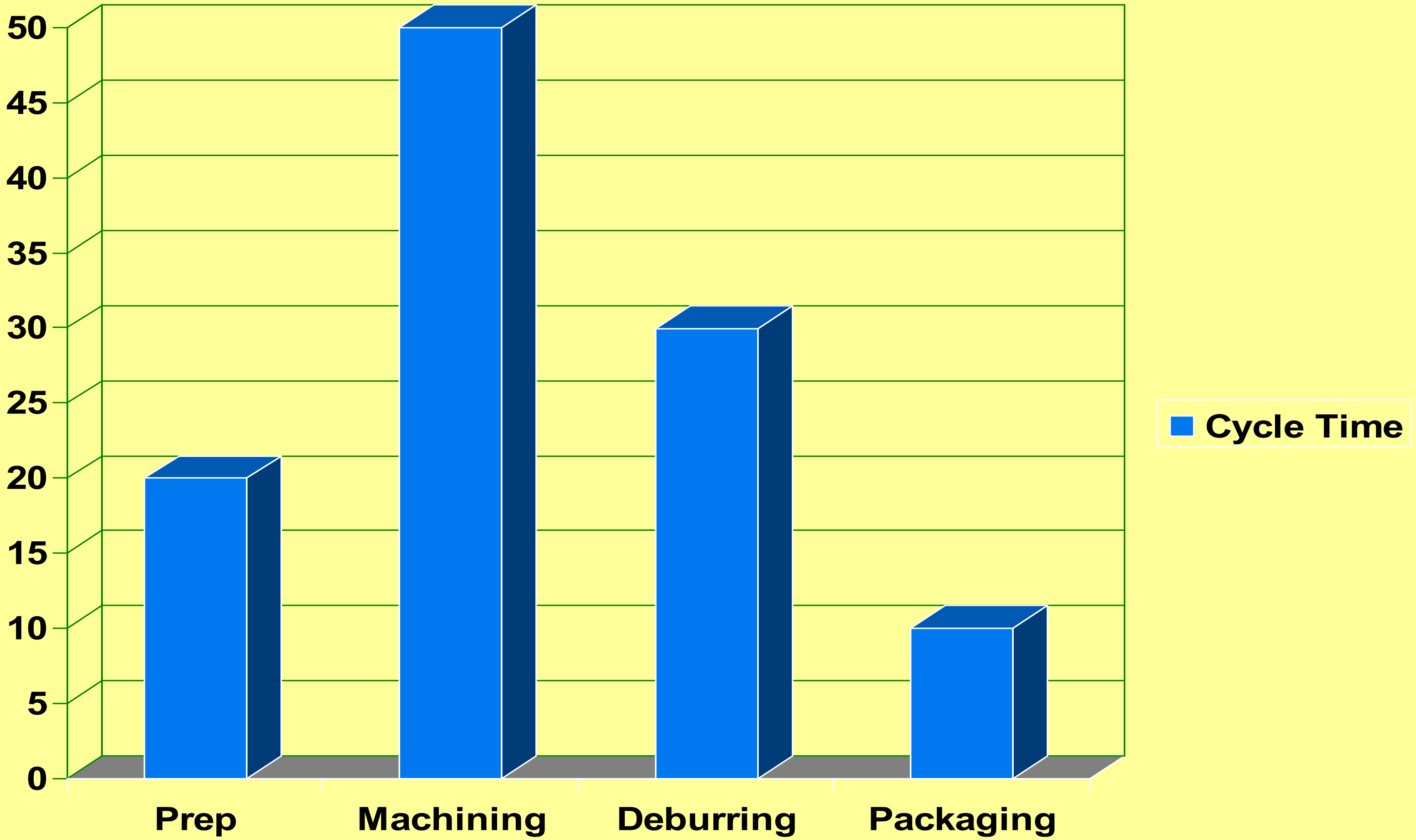
Throughput

The desired process throughput is inverse takt time.

Yield

The amount of product during a processing cycle

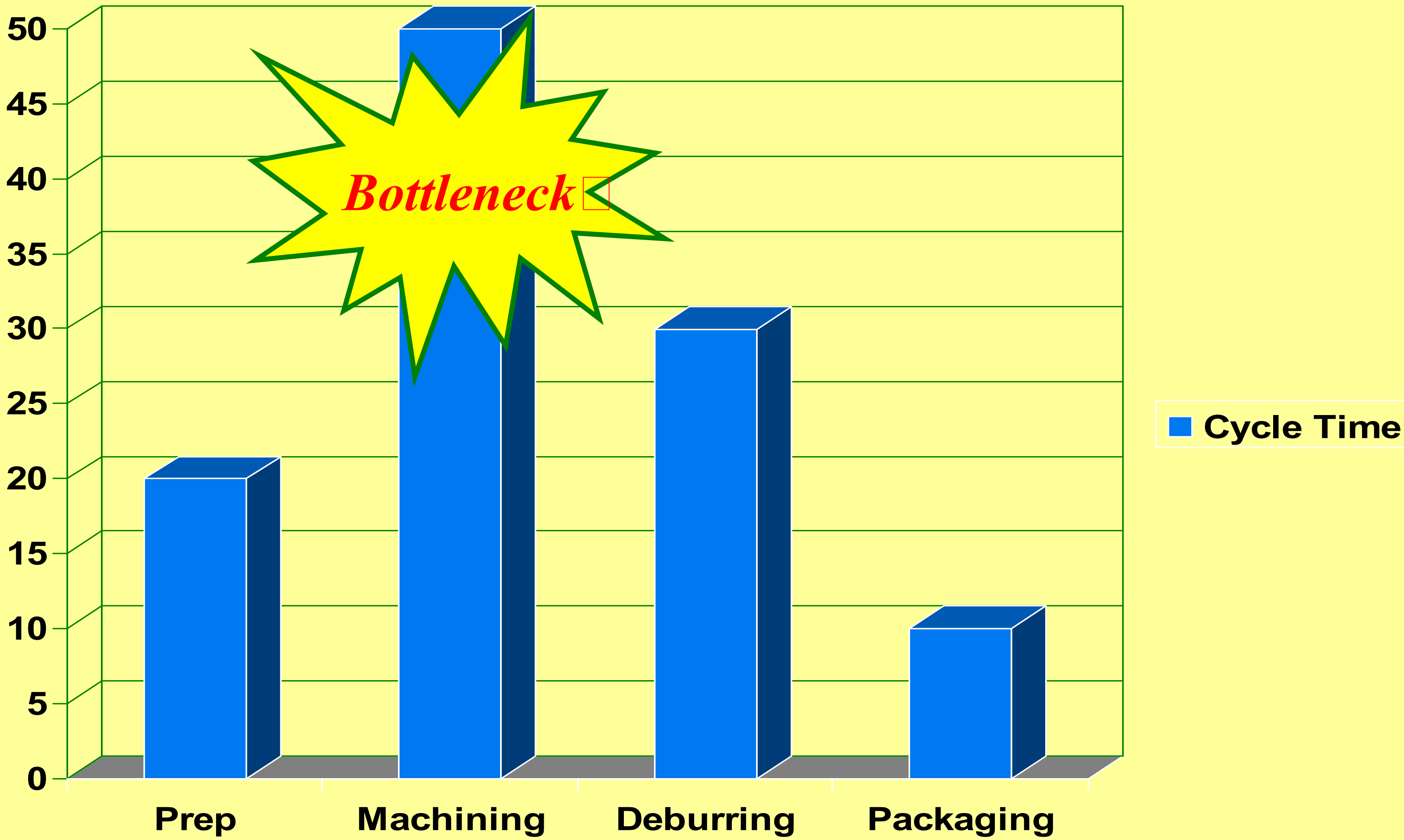
The Cycle Time Metric



Once the unit cycle times are known, *then what? Go Lean!*

- Where are we?
  - Determine process bottlenecks
- Where are we going?
  - Ability to forecast process capacity based on cycle time at the narrowest bottleneck
  - Assess bottleneck cycle times to prioritize continuous improvement/lean initiatives…*why improve cycle time?*
    - Continuous improvement may displace workers, as a reduction in cycle time often results in making more, faster, with fewer resources.
    - There needs to be a plan for dealing with changing resource requirements.
- How will we get there?
  - Combine cycle time with takt time and available work time to schedule production and labor allocation.
  - Create a detailed action plan that aligns all activities.

The Cycle Time Metric



Cycle Time at Work

Product Demand

500 units

Available Work Time

1 shift/day = 8.5 hrs – 0.5 hr (lunch) – 0.5 hr (breaks)=

450 mins.

Takt Time

450 mins./500 units =

54 secs./unit

The average time to make one unit of product. Inverted, it is the average throughput for the process.

Process Cycle Time

Σ(cycle times of each unit operation in the process) =

130 secs.

The time to complete a task or collection of tasks from beginning to end.

Work Balance

 # Work Cells (or operators) =

Process Cycle Time/Takt Time =

2.4 cells (operators)

Takt and Cycle Time Exercise

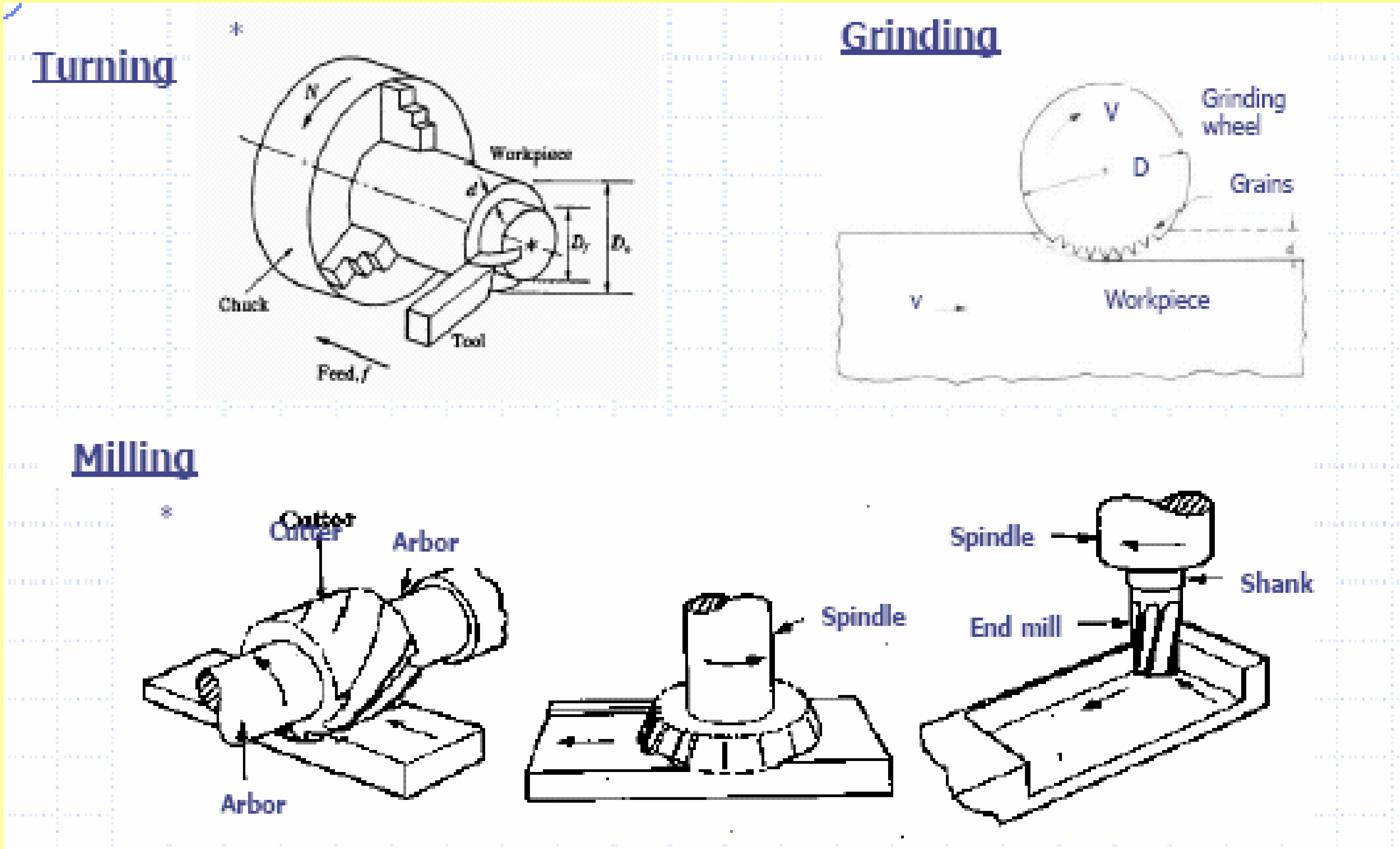
Machining Operations

- Four volunteers
- Demonstrate Mass Production model
- Demonstrate Lean Production model

Notes

- Position volunteers at stations with a varied work load at each.
- Processing involves passing "stock" from station to station
- Conduct a production run.
- Observe the "factory dynamics."
- Use balancing techniques to smooth the operation.

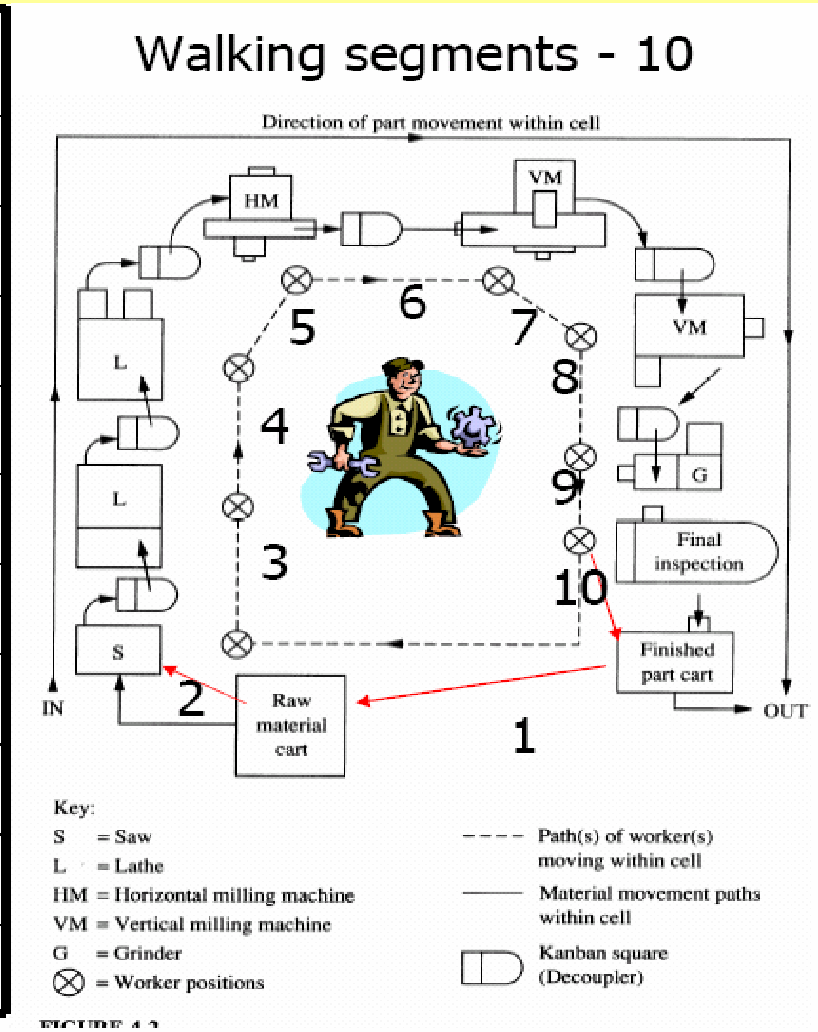
Machining Operations



Adapted from T. Gutowsky, Course 2.810

Machining Cell Cycle Times

	Manual (Sec)	Walk (Sec)	Machine (Sec)
Raw		3	
Saw	15	3	60
L1	10	3	70
L2	12	3	50
HM	12	3	120
VM1	20	3	70
VM2	20	3	60
G	15	3	60
F.I.	19	3 + 3	
Totals	**M+W**	**= 153**	**490**



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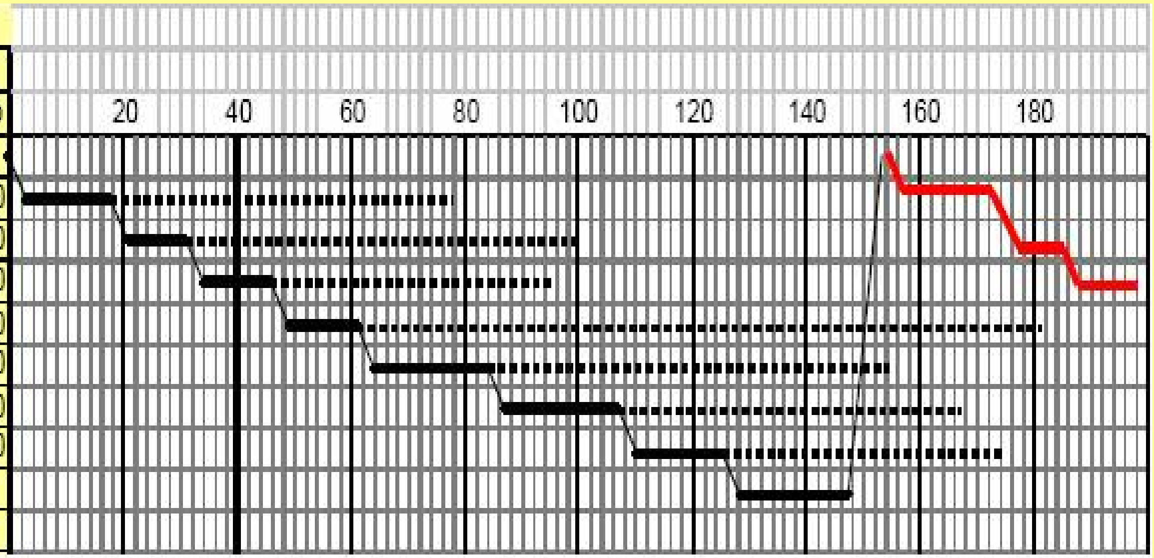
Machining Cell Cycle Times

PAJT. Black Cell		Operators:		
PROCESS		TIME (secs)		
#	OPERATION	Man	Walk	Auto
1	Raw		3	
2	Saw	15	3	60
3	L1	10	3	70
4	L2	12	3	50
5	HM	12	3	120
6	VM1	20	3	70
7	VM2	20	3	60
8	G	15	3	50
9	F.I.	19	6	



Cell produces one part every 153 sec

Note: machine time Max (MTj) < cycle time CT

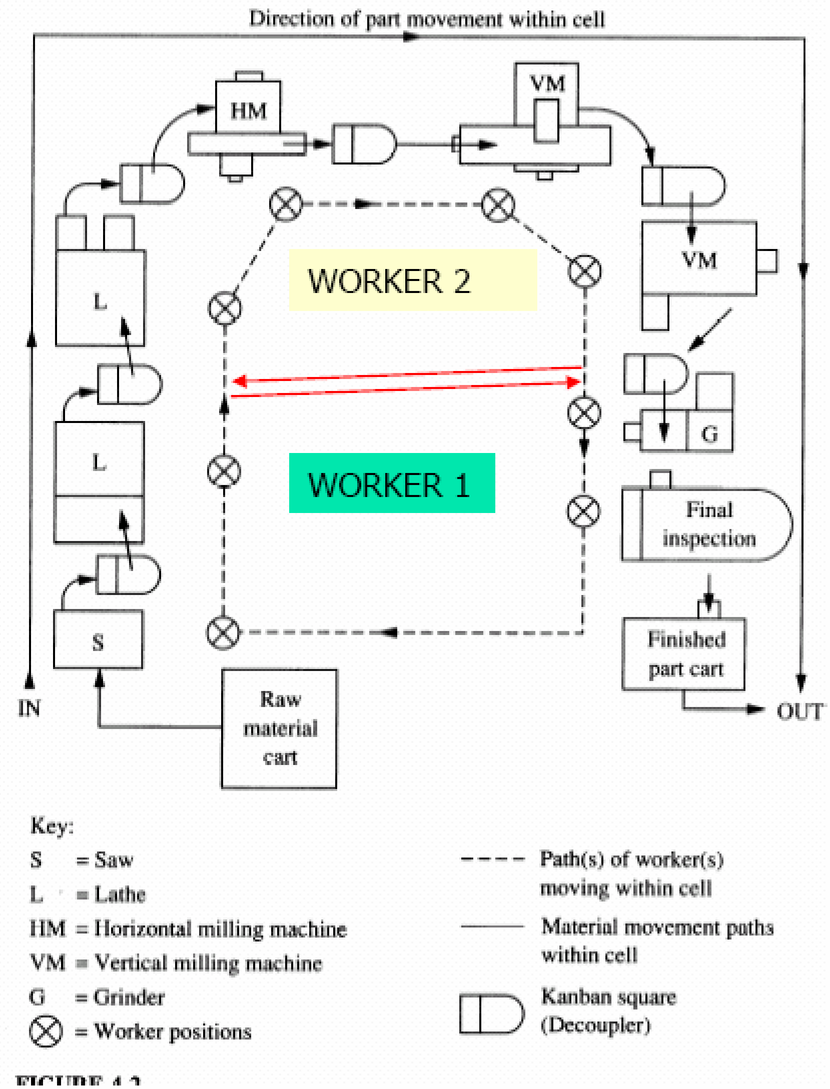
i.e. 120+12 < 153

Adapted from T. Gutowsky, Course 2.810

Machining Cell Cycle Time Optimization

	Manual (Sec)	Walk (Sec)	Machine (Sec)
Raw		3	
Saw	15	3	60
L1	10	3+3	70
L2	12	3	50
HM	12	3	120
VM1	20	3	70
VM2	20	3+3	60
G	15	3	60
F.I.	19	3 + 3	
Totals	**M+W**	**= 159**	**490**
Work 1		**80**	
Work 2		**79**	

To increase production rate add 2nd worker



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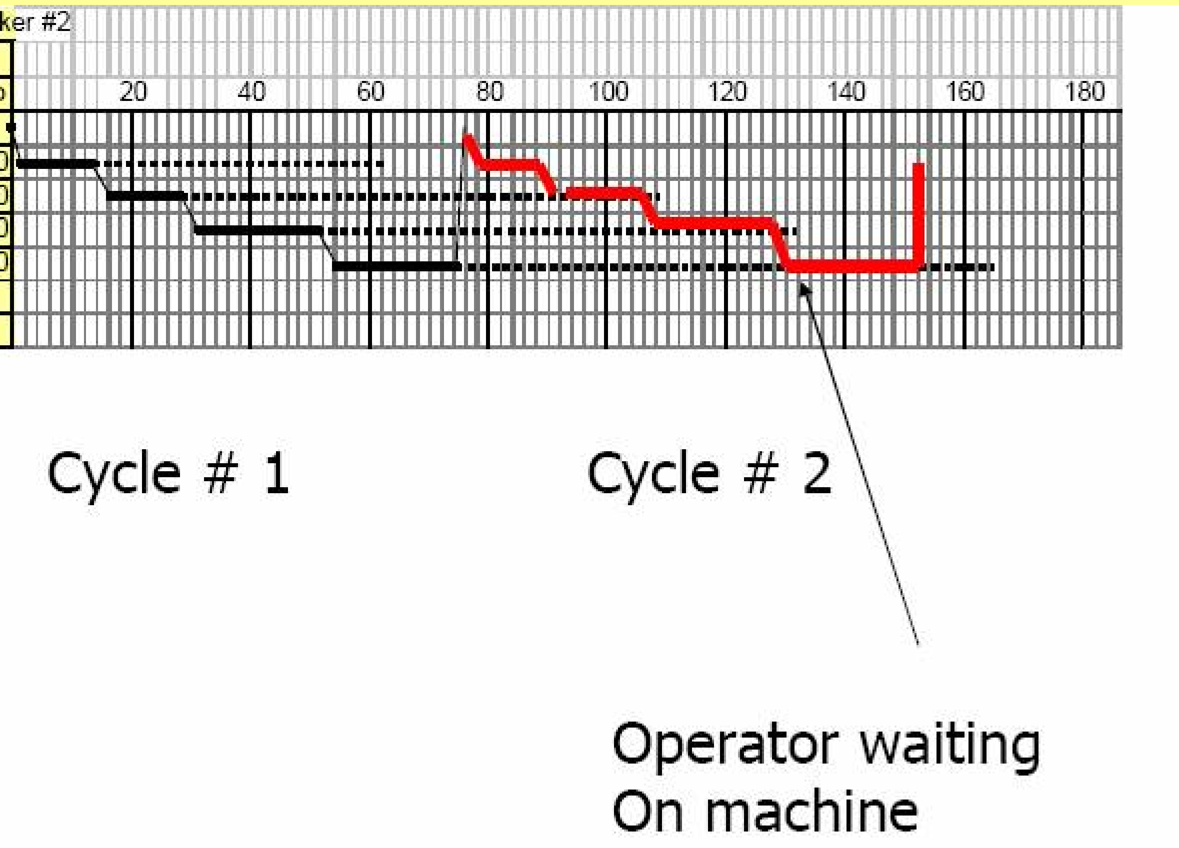
Step 1 Limitations

Rod Support	Operators: Worker #2		
OCESS	TIME {secs}		
OPERATION	Man	Walk	Auto
from decoupler		1.5	
L2	12	3	50
HM	12	3	80
VM1	20	3	80
VM2	20	1.5	90



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Step 1: Add Additional Worker

- Check max (MTj) < CT

Worker 1, 80 = 80

Worker 2, 12 + 120 > 79

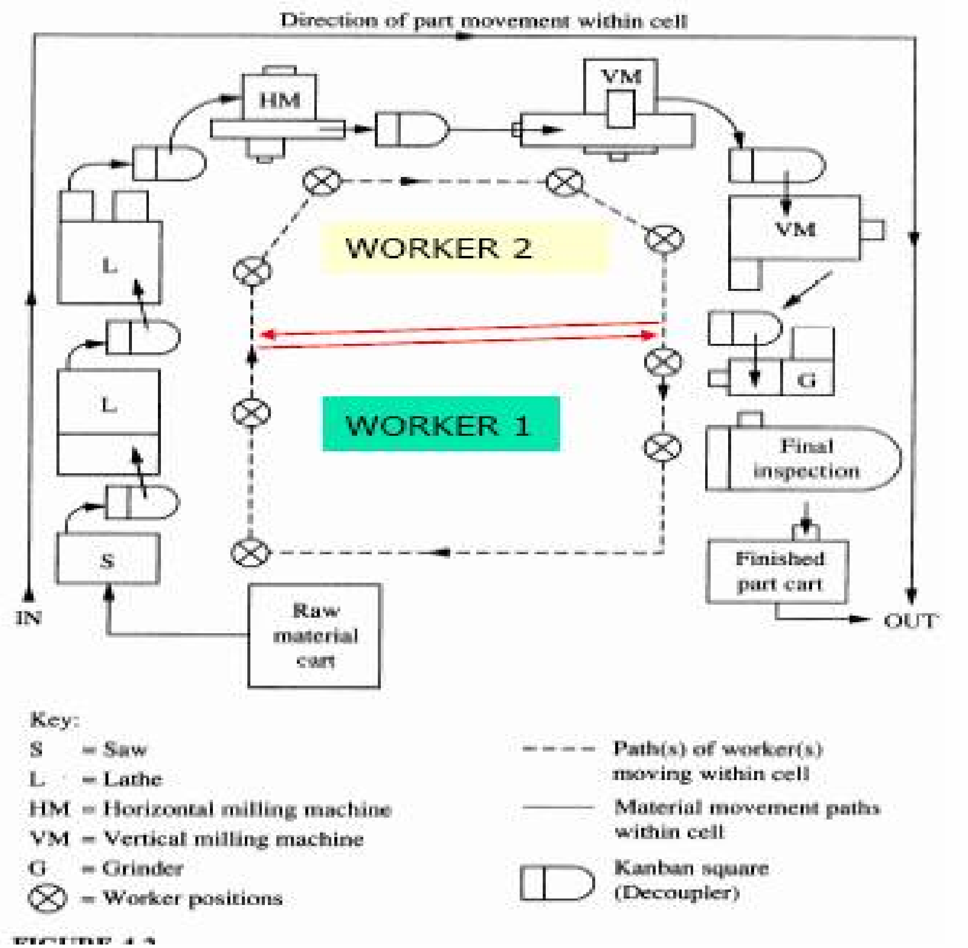
↳ **One part every 132 seconds**

- Can the work be shifted off the HM to reduce cycle time?

Adapted from T. Gutowsky, Course 2.810

Step 2: Balance the Load

	Manual (Sec)	Walk (Sec)	Machine (Sec)
Raw		3	
Saw	15	3	60
L1	10	3+3	70
L2	12	3	50
HM	12	3	120 → 80
VM1	20	3	70 → 80
VM2	20	3+3	60 → 90
G	15	3	60
F.I.	19	3 + 3	
Totals	**M+W**	**= 159**	**490**
Work 1		**80**	
Work 2		**79**	



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Step 2: Reduced Cycle Time

- Check max (MTj) < CT

Worker 1, 80 = 80

Worker 2, 110 > 79

- Hence, Worker 2 will need to wait for Vertical Mill #2

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Summary of Cycle Time Reduction

- The new production rate is

1 part/110 sec

- Cons:
  - Worker is "idle"
  - Can't speed up by adding additional worker

- In order to design for flexibility, make

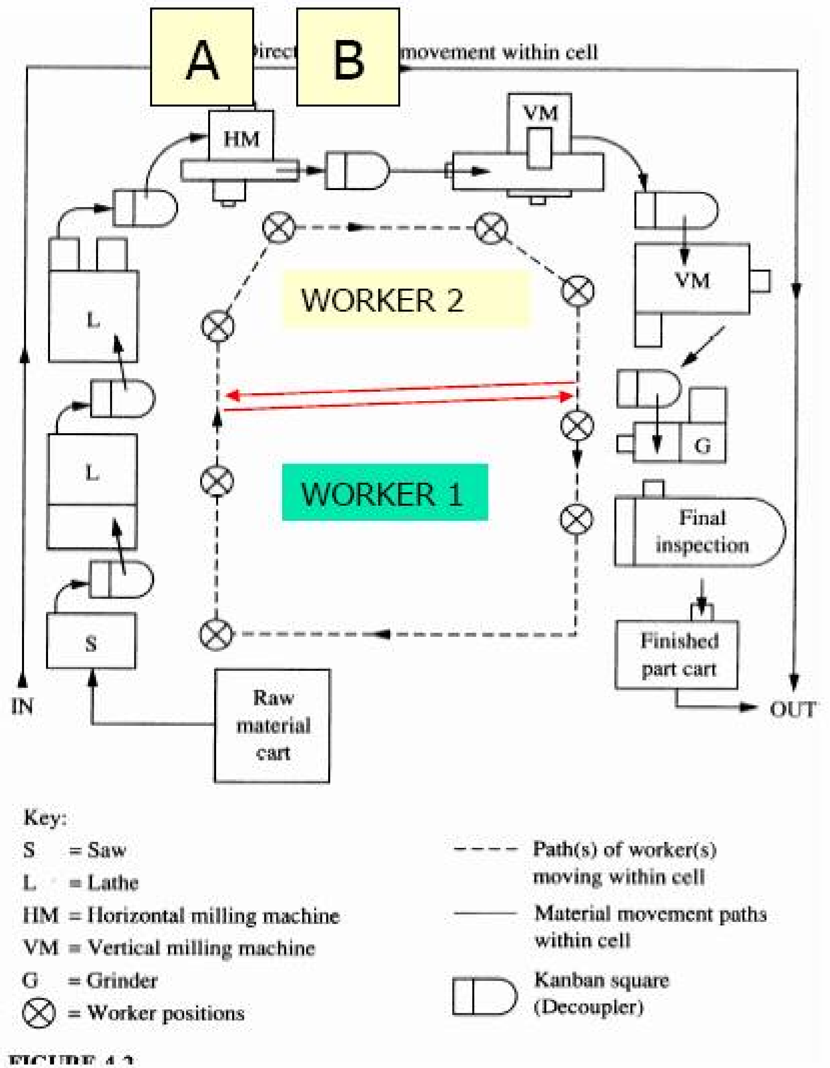
$$\text{Max (MTj)} < \text{CT}/2$$

Adapted from T. Gutowsky, Course 2.810

Alternative Cycle Time Reduction Plan

	Manual (Sec)	Walk (Sec)	Machine (Sec)
Raw		3	
Saw	15	3	60
L1	10	3+3	70
L2	12	3	50
HM	12	3	120
VM1	20	3	70
VM2	20	3+3	60
G	15	3	60
F.I.	19	3 + 3	
Totals	**M+W**	**= 159**	**490**
Work 1		**80**	
Work 2		**79**	

Alternative solution add 2 HM's



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Connecting Cycle Time to Lean

- In a mass production setting, cycle time improvements are driven by management with the goal of maximizing machine productivity.
  - Cycle time improvements, such as that shown in step one, are easy for management to drive because machines are idle.
- In the Lean Model, cycle time improvements are driven by workers, based on their knowledge of the work and equipment, with the goal of increasing value added work and minimizing non-value added work.
  - Cycle time improvements, such as that shown in step two, require an intimate familiarity of both product and process that workers possess.

Disconnects

- ***Technical Factors***
  - **Relating cycle time to other performance metrics, such as yield and first-pass throughput**
  - **Prioritizing cycle time improvements to minimize production interruptions**
  - **Knowing when cycle time improvement is not the answer to productivity problems, e.g. when poor yield is a quality issue not a throughput issue**
- ***Social Factors***
  - **Better communication in scheduling product orders to minimize set-up time and maximize production time**
  - **The knowledge possessed by the workers signifies the strongest leveraging point in an organization to drive continuous improvement.**

Measurables

- A key measure of cycle time performance is customer satisfaction.
- Can the process meet customer expectations consistently and without a lot of last minute scrambling to meet deadlines?
- Are cycle times optimized to minimize equipment and personnel idle time? Align unit cycle times to takt time to minimize processing inconsistencies.
- Are cycle times repeatable and reproducible over the long run? Variable cycle times may cause product quality issues and customer dissatisfaction.

In Conclusion

- Cycle time is a key indicator of process and equipment performance.
- Machining operations rely on consistent cycle times to schedule production and allocate labor.
- Leverage your knowledge base to drive improvement
- Questions?

Appendix: Instructor's Comments and Class Discussion on 8.2

- Cycle time is linked to other aspects of lean/ six sigma
  - Continuous improvement leads to stepped improvement in cycle once takt times come down for all steps
  - Standardized work is key to making cycle time work on the floor
- This module is particularly focused on machining operations, where cycle time is machine paced (in contrast to assembly operations)

Appendix: Instructor's Guide

Slide	*Time*	*Topic*	*Additional Talking Points*
1-2	2-3 min	Introduction, overview and learning objectives	• Identify overall themes.
3-7	3-5 min	Key Concepts	• Discuss how cycle time relates to determining process bottlenecks. •Discuss the relationships between cycle time, takt time, and available work time in production scheduling.
8-18	7-10 min	Exercises/Activities	• Perform group exercise and highlight learning points. •Discuss Cycle Time as it pertains to machining operations.
19	5-7 min	Disconnects	• Discuss pertinent disconnects in understanding the import of developing cycle time metrics.
20	2-3 min	Measurables	• Discuss key measurables of cycle time performance, e.g. customer satisfaction and product quality.
21	1-2 min	Concluding comments	• Wrap up discussion. •Field questions from the audience.

Bibliography

- Dennis, Pascal. *Lean Production Simplified.* New York: Productivity Press, 2002.
- Strategos-International. *Future State Value Stream: Mapping the Future State Site.* Cited June 28, 2004. Available from http://www.strategosinc.com/vsm2.htm.