

# Continuous Flow Operations

## Module 8.3

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**Presentation for:**

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*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

- What is a continuous flow operation?
- What considerations are critical to the business?
- How do lean principles apply to a continuous flow operation?

## ➤ 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.)*

# Continuous Flow Operations

- The ability to maintain steady state conditions in flow and concentration through the modules of the system<sup>1</sup>
- Examples include:
  - chemical synthesis
  - Some food manufacturing (chocolate, beer)
  - water processing
  - energy generation
  - information technology

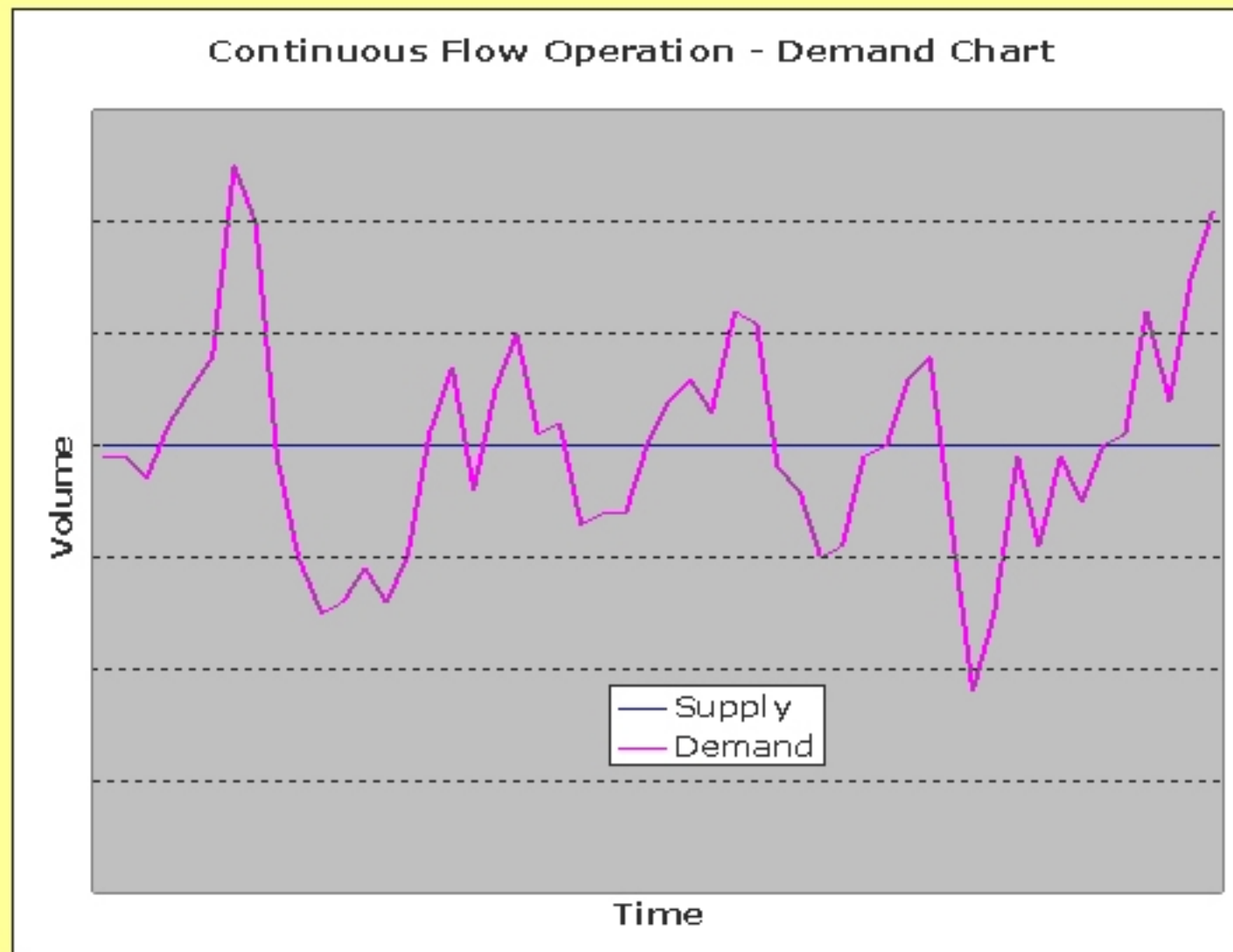
# Continuous Flow – Defining Factors<sup>2,3</sup>

- High product volume
- Special purpose equipment (low flexibility)
- Uninterrupted product flow
- Few schedule changes
- Low number of standardized products
- Low variable cost (up to capacity level)
- Low labor skill (operators) during regular operations

# Continuous Flow – Critical Factors

- Capital intensive (start-up)
- Storage of in-process and finished goods
- Material waste or loss
- Maintenance costs
- Fluctuations in demand
- Supply of finished goods is usually constant
- Products often become commodities
- Economies of scale (usually bigger is better)

# Typical Continuous Flow Supply vs. Demand



Variability of demand is the challenge in continuous flow operations

# Continuous Flow – Lean Parameters

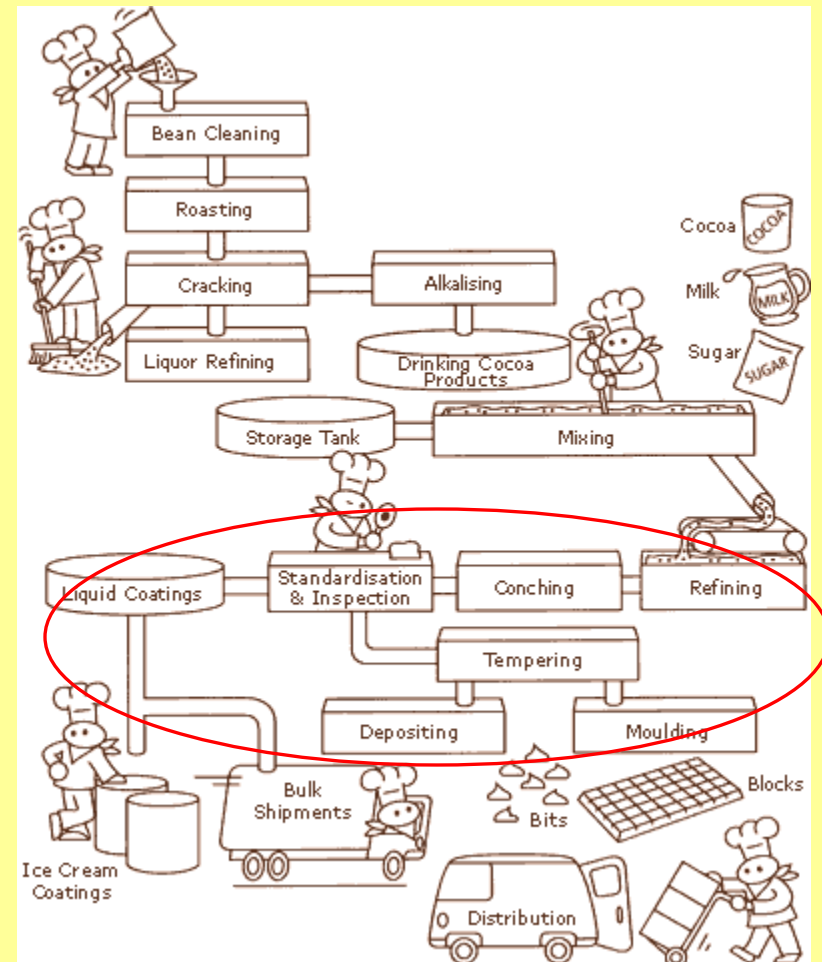
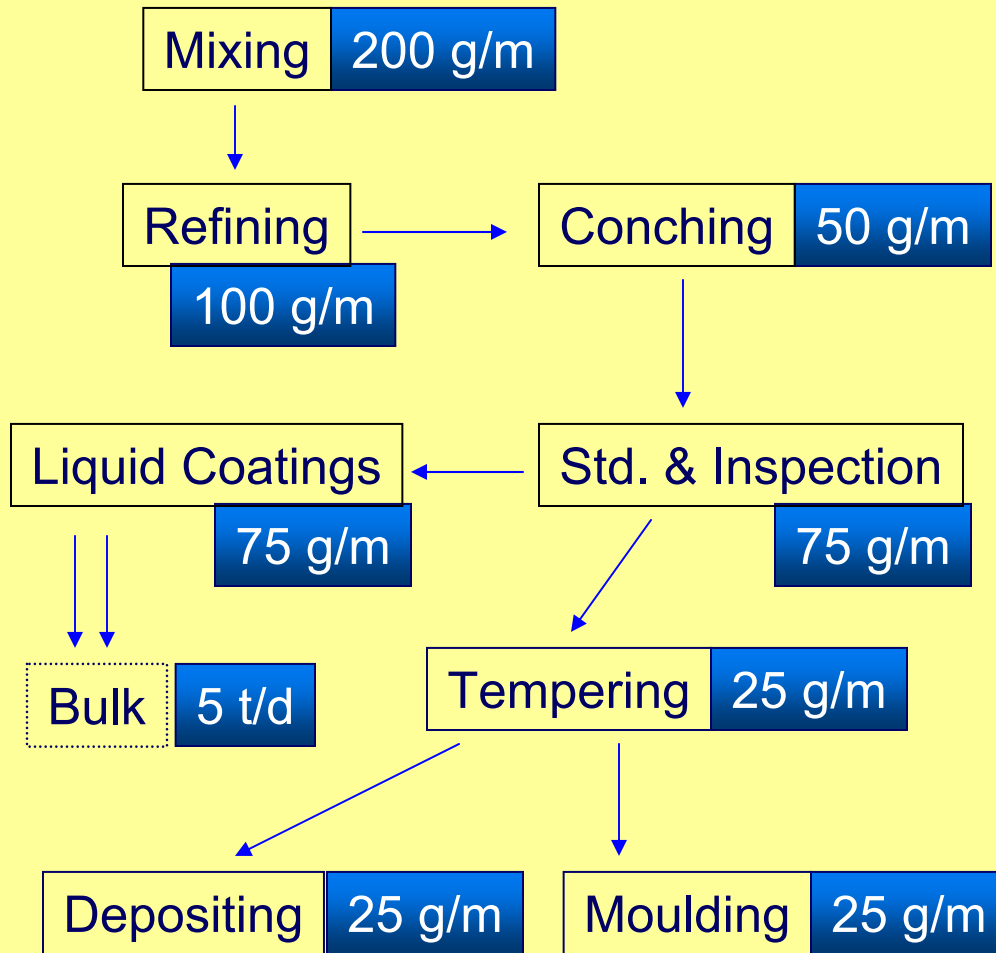
- Initial engineering design is critical
  - Change in production quantity
  - Introducing additional equipment
- In-line sensing
- Preventative Maintenance
- Overall Equipment Effectiveness
- Equalization of Takt times (Line balance)
- Accurate forecasting of demand

# Initial design and sensing concerns

- Initial design should take into account:
  - Ease of maintenance
  - Ability to expand/reduce production
  - Changing input costs
  - Preventative maintenance
  
- Sensing:
  - Can evaluate qualitative factors with quantitative information
  - Helps drive process improvement
  - Can detect equipment problems in un-viewable areas

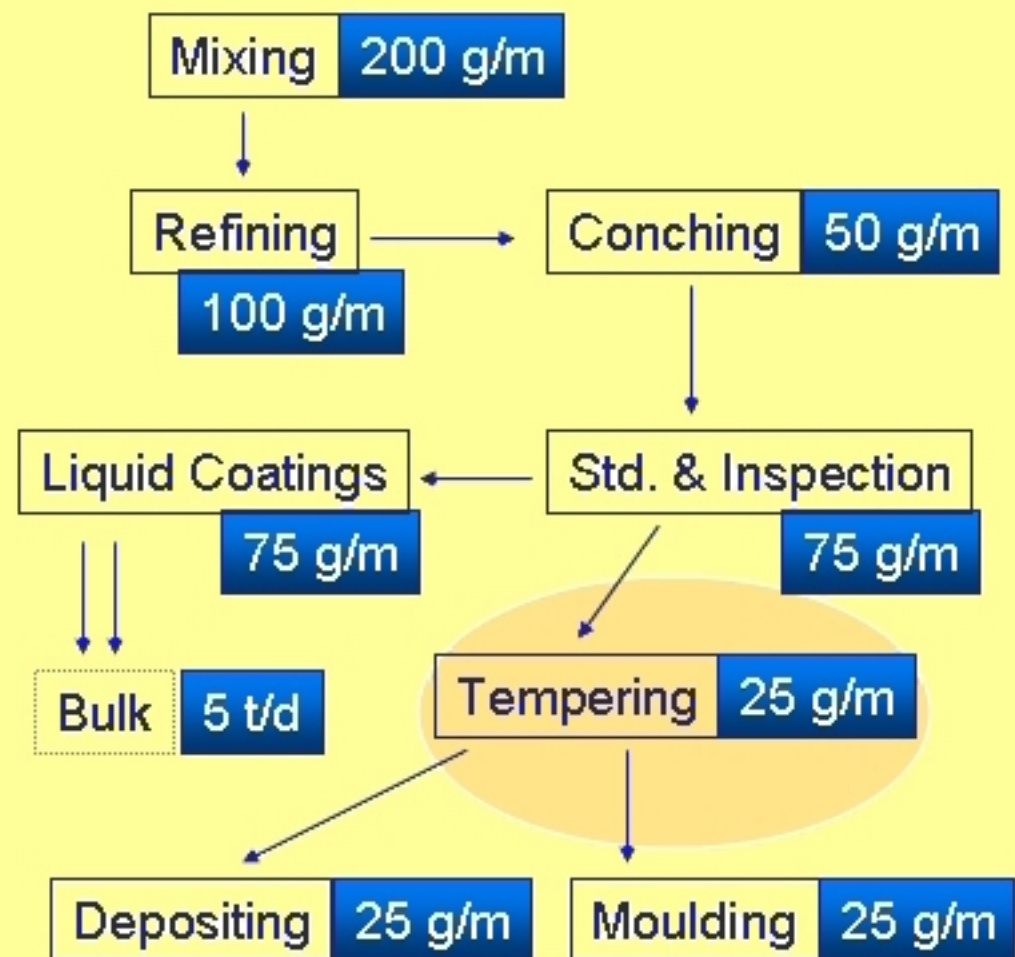


# Chocolate Production Flow



# Questions

- What is the maximum flow?
  - 25 g/m
- Where is the bottleneck?
  - Tempering
- What are other limiting factors?
  - Conching
  
- How can we fix the system?



# Overall Equipment Effectiveness

- $OEE = \text{Availability} \times \text{Performance Rate} \times \text{Quality Rate}$
- $\Delta$  between capability and real output
- Options:
  - Inspect equipment for flaws, repair
  - Test equipment
  - Check original design document (original specifications)
  - Add inline tempering/conching unit (additional capacity)

*Availability (operating time/net available time) X*  
*Performance ((ideal cycle time x total parts run)/operating time) X*  
*Quality ((total parts run - total defects)/total parts run)*

# Disconnects

## ➤ Technical Factors

- Supply is typically constant, hard to change in a Brownfield operation
- Initial design might not account for later improvements
- Maintenance more difficult (downtimes may not exist)
- High cost of production step-function

## ➤ Social Factors

- Demand is typically variable
- Operators typically have little input (chemical reactors, generators), so harder to get continuous improvement
- High competition for lowest cost, commodity game

# Measurables

- OEE = Availability x Performance Rate x Quality Rate
- Improved forecasting of demand can lead to more narrow control limits ( $\sigma$ )
- Statistical data from sensing to improve quality



# Concluding Comments

- Typical situations are Brownfield operations where initial design is sub-optimal. In these cases capital improvements may be difficult based on earlier designs.
- Cost of changing capacity can also be high because of similar Brownfield considerations. (Ex. Power plant)
- Important tools include the OEE for establishing line balance and reducing bottlenecks.



# Appendix: Instructor's Comments and Class Discussion

- Key issue in continuous flow industries: balancing supply and demand
  - Economies of scale lead to continuous, large scale production—often more than market demands
  - Apparent economies become disabilities
  - Process industries often use financial instruments to make up for inability to scale to demand
- Socio-tech teams are often used instead of lean teams, since there is more meeting time and global focus on plant is required
- Scope of OEE is important: it can be for an individual machine, the bottleneck operation, an production operation or line, or an entire plant

# Appendix: Instructor's Guide

<b>Slide</b>	<b>Time</b>	<b>Topic</b>	<b>Additional Talking Points</b>
1-2	2-3 min	Introduction, overview and learning objectives	<ul style="list-style-type: none"> <li>•What is a CF process? Business Applications? Lean applications in CF environment?</li> </ul>
3	2 min	Key Concepts - Continuous Flow Operations	<ul style="list-style-type: none"> <li>•A perfectly lean discrete operation could be considered "continuous." However, this is not subject of this SPL.</li> </ul>
4-8	5-8 min	Key Concepts (con) - Defining factors, Critical factors, Graph, and lean parameters.	<ul style="list-style-type: none"> <li>•The characteristics (defining factors)</li> <li>•Example of capital expenses are a plant being run even though it is losing money because it costs more money to shut it down.</li> <li>•Maintenance costs - sometimes as high as 10% of sales</li> <li>•Commoditization of product - price set by market, lowest cost provider is winner</li> <li>•For graph (slide 6) - Area under curves match, but costs of straight supply are in not meeting demand (losing customers) and excess finished goods inventory. Ideally the will match and any system that is designed to be responsive over a shorter and shorter piece of time will be more effective.</li> </ul>
9-10	7-10 min	Exercises/Activities - Chocolate factory	<ul style="list-style-type: none"> <li>•Look at system flow and its constraints. If we are looking at different objectives, then the limiting factor will change. This example looks at maximum available for depositing and moulding.</li> </ul>
11	1-2 min	Overall Equipment Effectiveness	<ul style="list-style-type: none"> <li>•Basic method for balancing line flow. As a consultant you would first look at this.</li> </ul>
12	5-7 min	Disconnects	<ul style="list-style-type: none"> <li>• Look for personal examples either from audience or from your own experiences</li> </ul>
13	2-3 min	Measurables	<ul style="list-style-type: none"> <li>• OEE</li> </ul>
14	1-2 min	Concluding comments	<ul style="list-style-type: none"> <li>• Lean happens at design. Design responsiveness to demand.</li> </ul>



# References

- Reference 1 - [http://weather.nmsu.edu/Teaching\\_Material/SOIL698/Student\\_Material/AutoAnalyzer/Flow.html](http://weather.nmsu.edu/Teaching_Material/SOIL698/Student_Material/AutoAnalyzer/Flow.html)
- Reference 2 – Adam, Everett E., Ebert, Ronald J. *Production and Operations Management*. Englewood Cliffs, NJ. Prentice-Hall. 1978.
- Reference 3 - <http://www.netmba.com/operations/process/structure/>
- Reference 4 - <http://www.maintenanceworld.com/Articles/feedforward/overall.htm>
- Figure 1 - [http://www.nestle.com.au/baking/beanToBlock/images/diagram\\_story\\_of\\_choc.gif](http://www.nestle.com.au/baking/beanToBlock/images/diagram_story_of_choc.gif)
- Image 1 - <http://www.eia.doe.gov/kids/images/Amoco.jpg>
- Image 2 - <http://www.waega.de/6thOct3.jpg>
- Image 3 - <http://www.titanicbrewery.com/images/brewery.jpg>