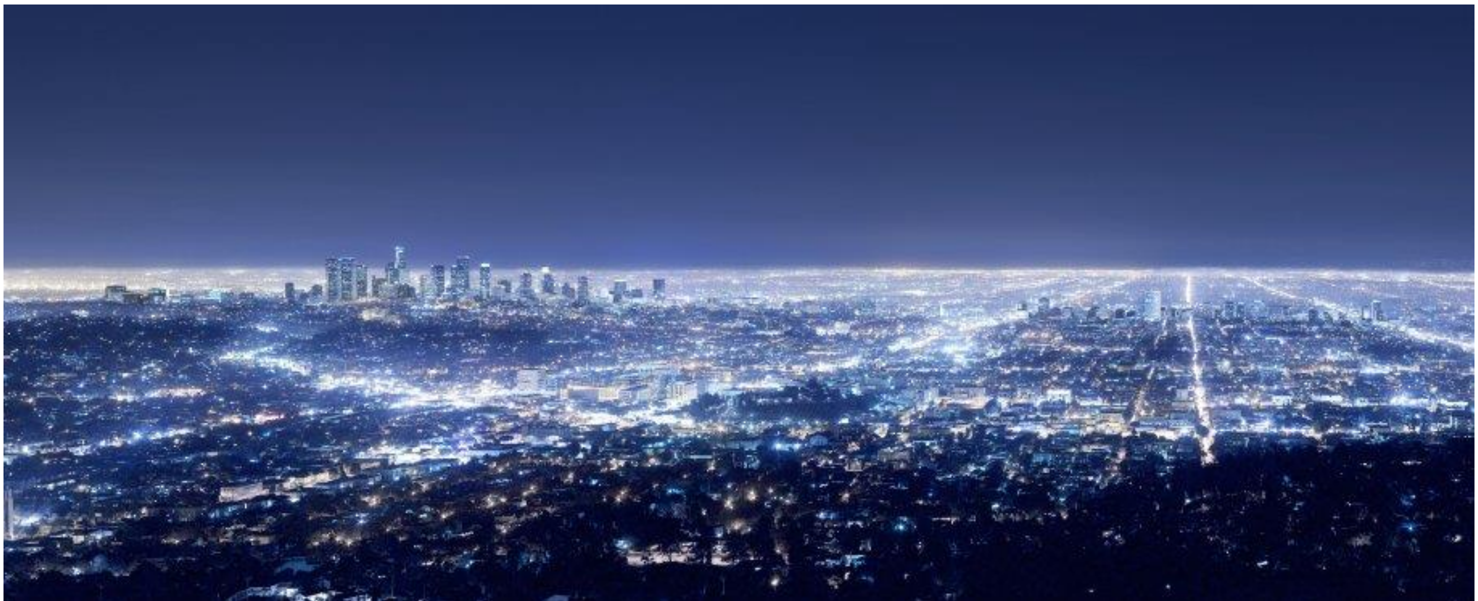


Factory Physics ® Analytics

with applications to Project Production

FactoryPhysics®
Strategy. Execution. Profit.

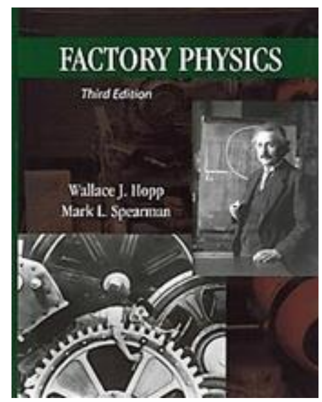
PPI

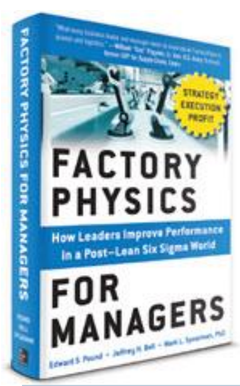
Why Factory Physics Analytics?

- Projects are like factories
  - Have deliverables with deadlines to meet a demand
  - Have capacity limitations in the productive processes
  - Can perform some production ahead of demand
  - Have variability in both "production" and demand
- Factory Physics addresses
  - Demand
  - Production
  - On time delivery
  - Variability
  - And how they interact

Factory Physics Inc

- Core Competence:
  - Wrote ‘the book’ on operations performance
  - IIE Book of the Year
  - Application of scientific principles to improving operations performance
- Clients
  - European, North and South American manufacturers





- Global Operations Based in U.S.A
  - Established in 2001 based on 22 years of research

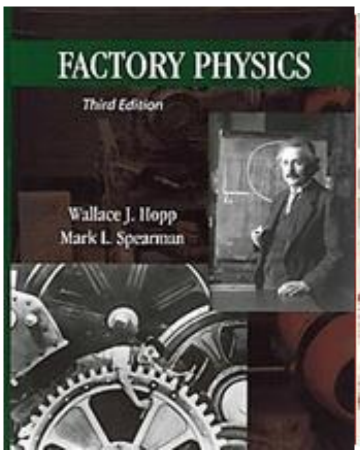
A consulting company with software.

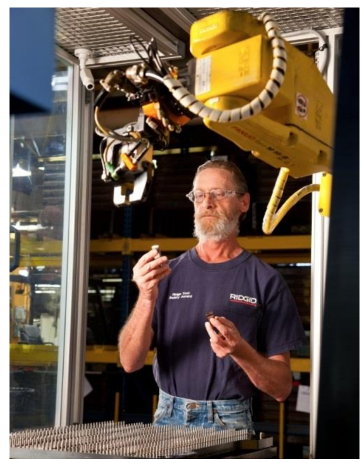
What makes this approach different?

- It is scientific—science relentlessly tested in industry
- It has software to standardize analysis and learning
  - Rapid modeling, data obtained from existing systems
  - Efficient frontier curves to quickly identify opportunities
  - Where do you want to operate? Where can you operate?

Ability Matrix	Current State Analysis		Future State Analysis	
Approach	**Speed**	**Detail**	**Predictive**	**Optimal**
Factory Physics Analytics	2 weeks	Moderate	Yes	Yes
Six Sigma	3+ months	NA	No	No
Lean	1 week	Low	No	No
Monte Carlo Simulation	3 months+	High	Yes	No

How to Profit from Science?



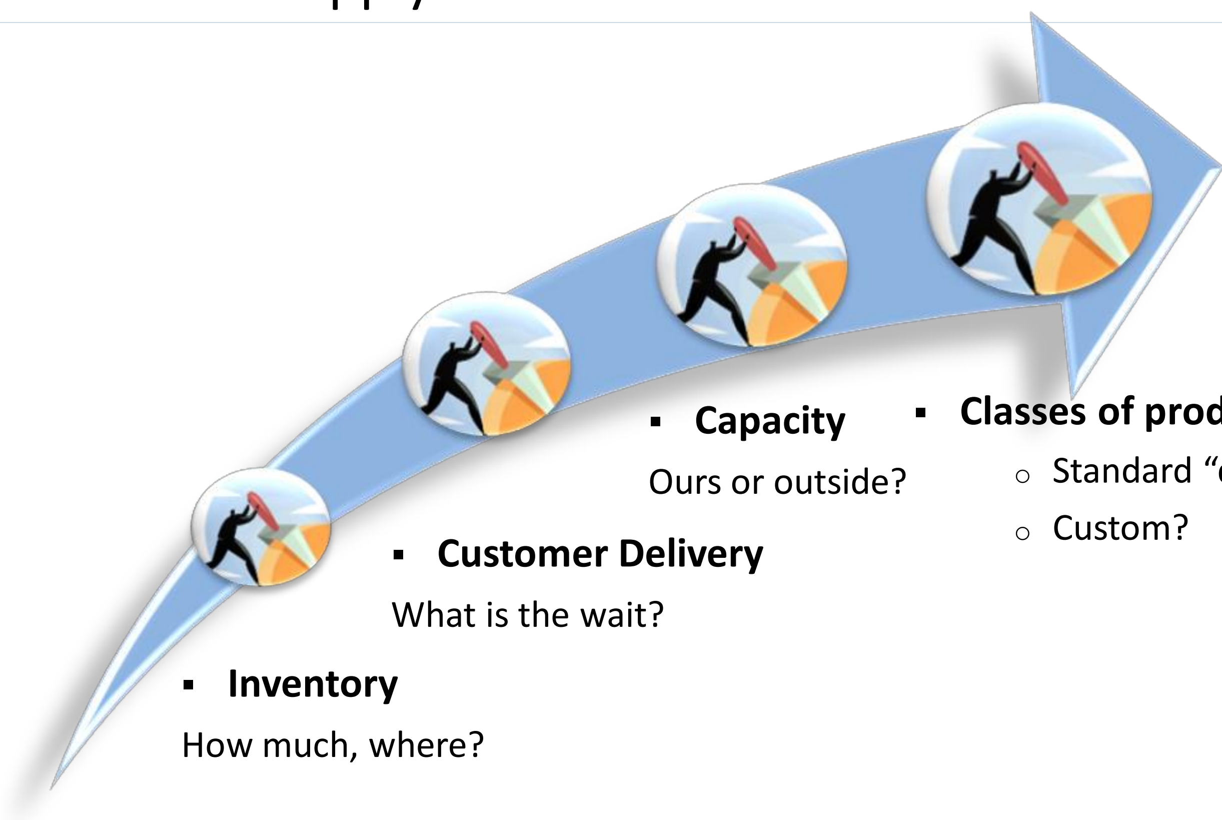


- What to make?
- When to make it?
- How much to make?

- How many people and machines do I need?
- How much inventory should I have?

Value Chain Excellence: High On-time delivery, low cost, low inventory

To drive profits, there are many levers a supply-chain executive must control



- **Inventory**

  How much, where?

- **Customer Delivery**

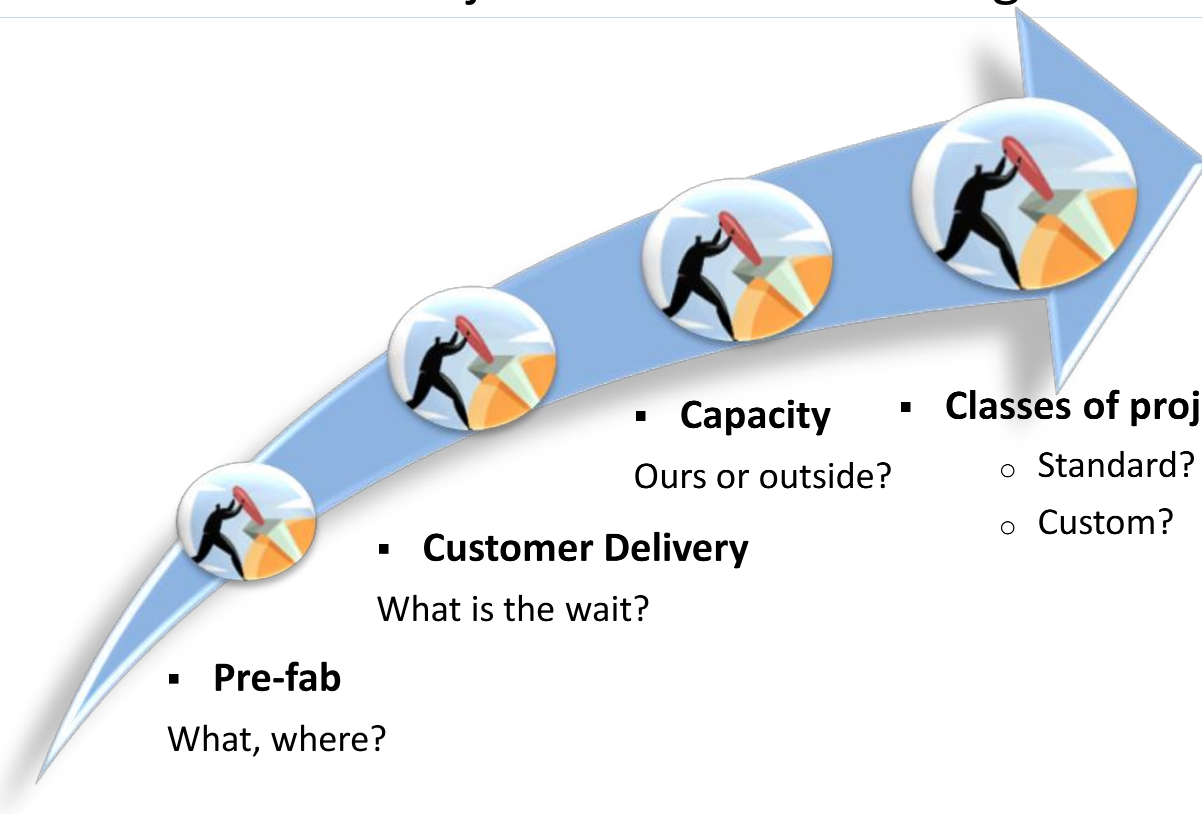
  What is the wait?

- **Capacity**

  Ours or outside?

- **Classes of product**
  - Standard “quick-ship”?
  - Custom?

The Project Production Manager



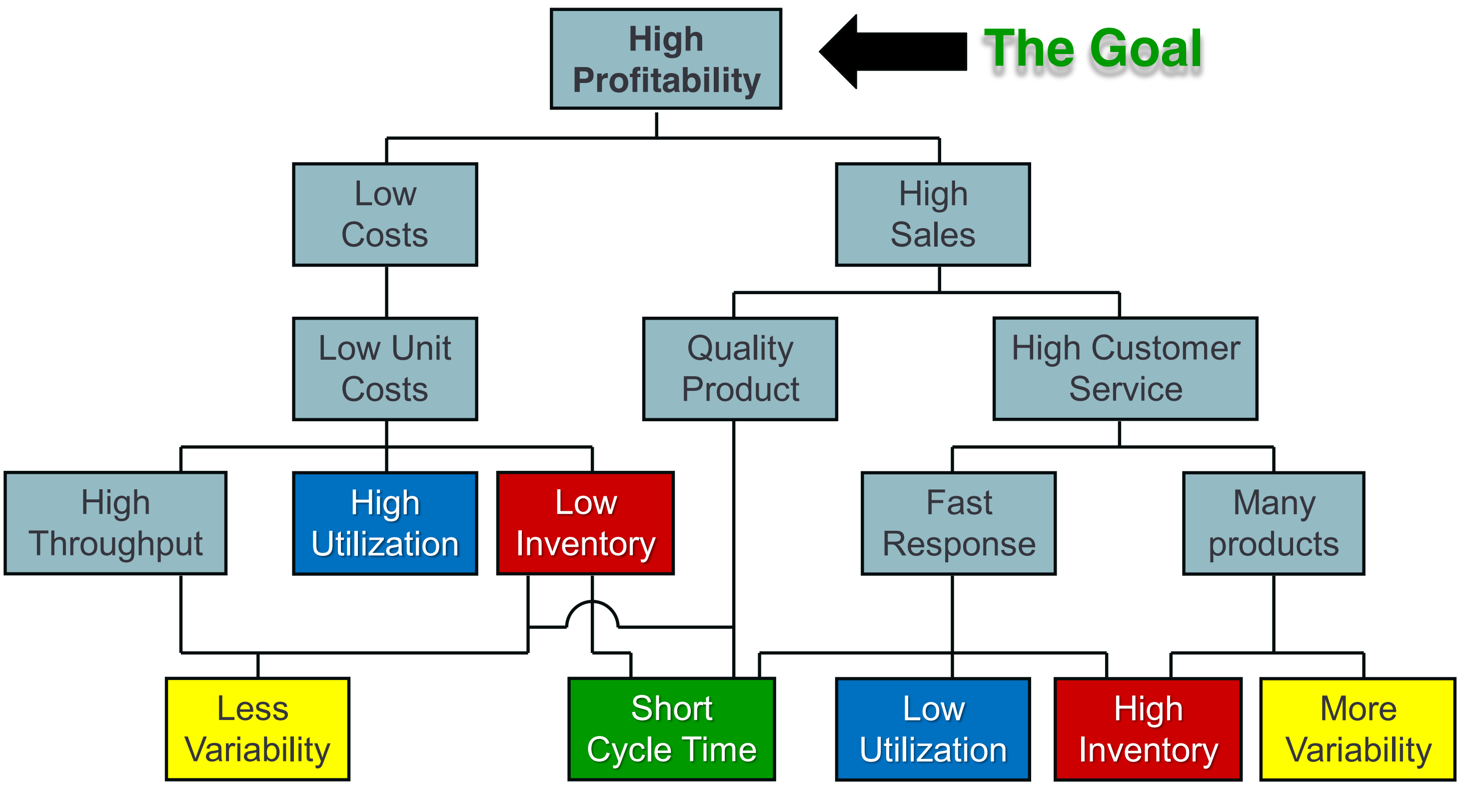
- **Pre-fab**

  What, where?
- **Customer Delivery**

  What is the wait?
- **Capacity**

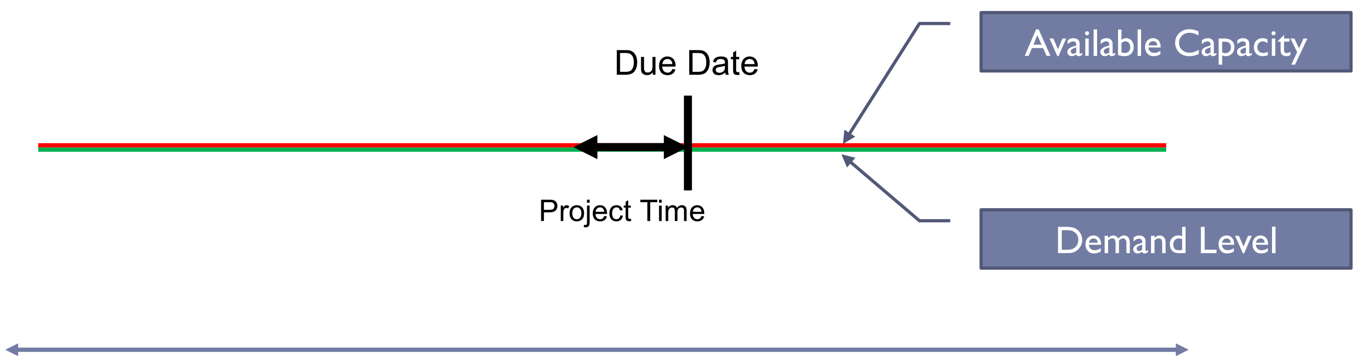
  Ours or outside?
- **Classes of project**
  - Standard?
  - Custom?

The goal of supply chain management

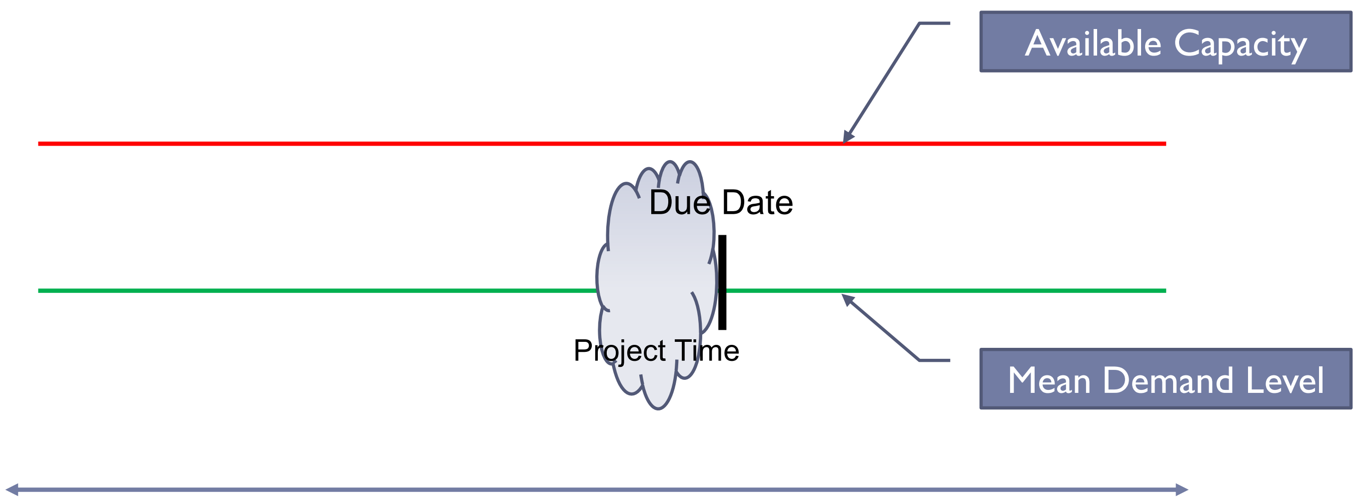


Many managers bounce back and forth and call it continuous improvement.

Project Production—no variability: demand = capacity, no waiting

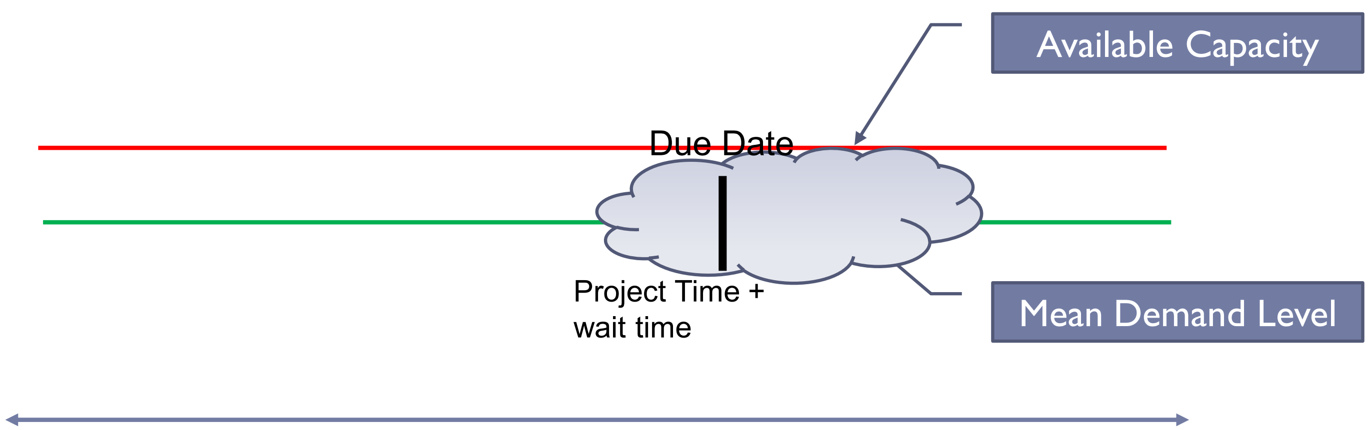


Project Production—with variability: capacity > maximum demand



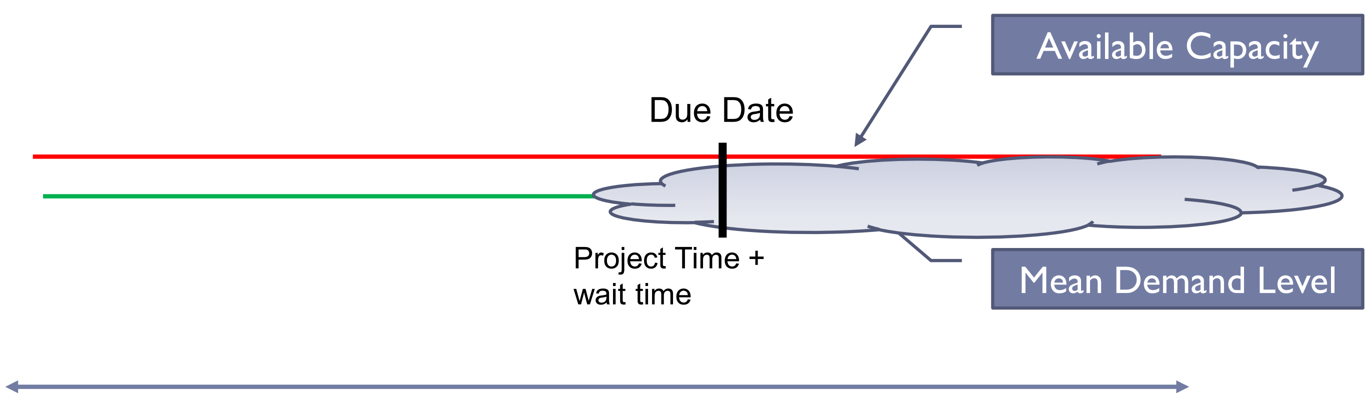
Start early but no waiting

Project Production—with variability: max dmd > capacity > mean dmd



Start early and still late

Project Production—with variability: little extra capacity



Start early and very late

The Fundamental Factory Physics® Framework

Two *essential* components

- Demand
- Transformation

Two *structural* elements

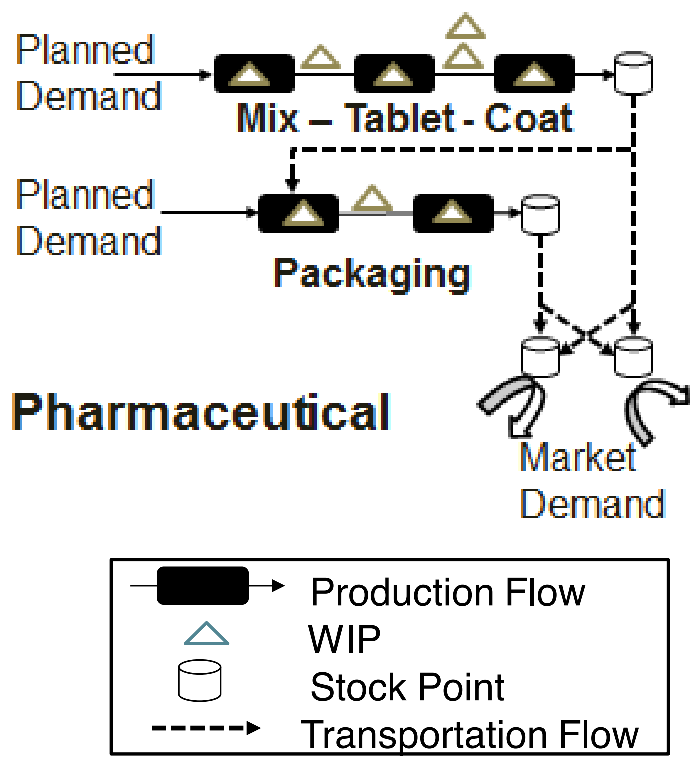
- Stocks
- Flows

Buffers develop when *variability* is present.

Only three buffers:

1. Inventory
2. Time
3. Capacity

Demand Stock Production Diagram

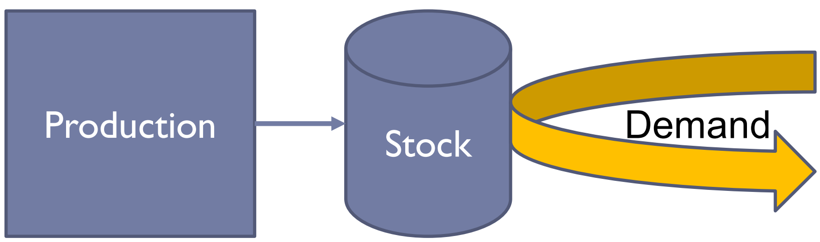


How it Works

$$
\begin{aligned}
d\mathbf{p} &= \left(\{\mathbf{p}, \mathcal{H}\} - \eta\mathbf{p}\right) dt + \beta dW \\
d\mathbf{q} &= \{\mathbf{q}, \mathcal{H}\} dt \\
\mathbf{p}(0) &= \mathbf{p}_0 \\
\mathbf{q}(0) &= \mathbf{q}_0
\end{aligned}
$$

There's physics behind Factory Physics science.

Demand—Stock—Production

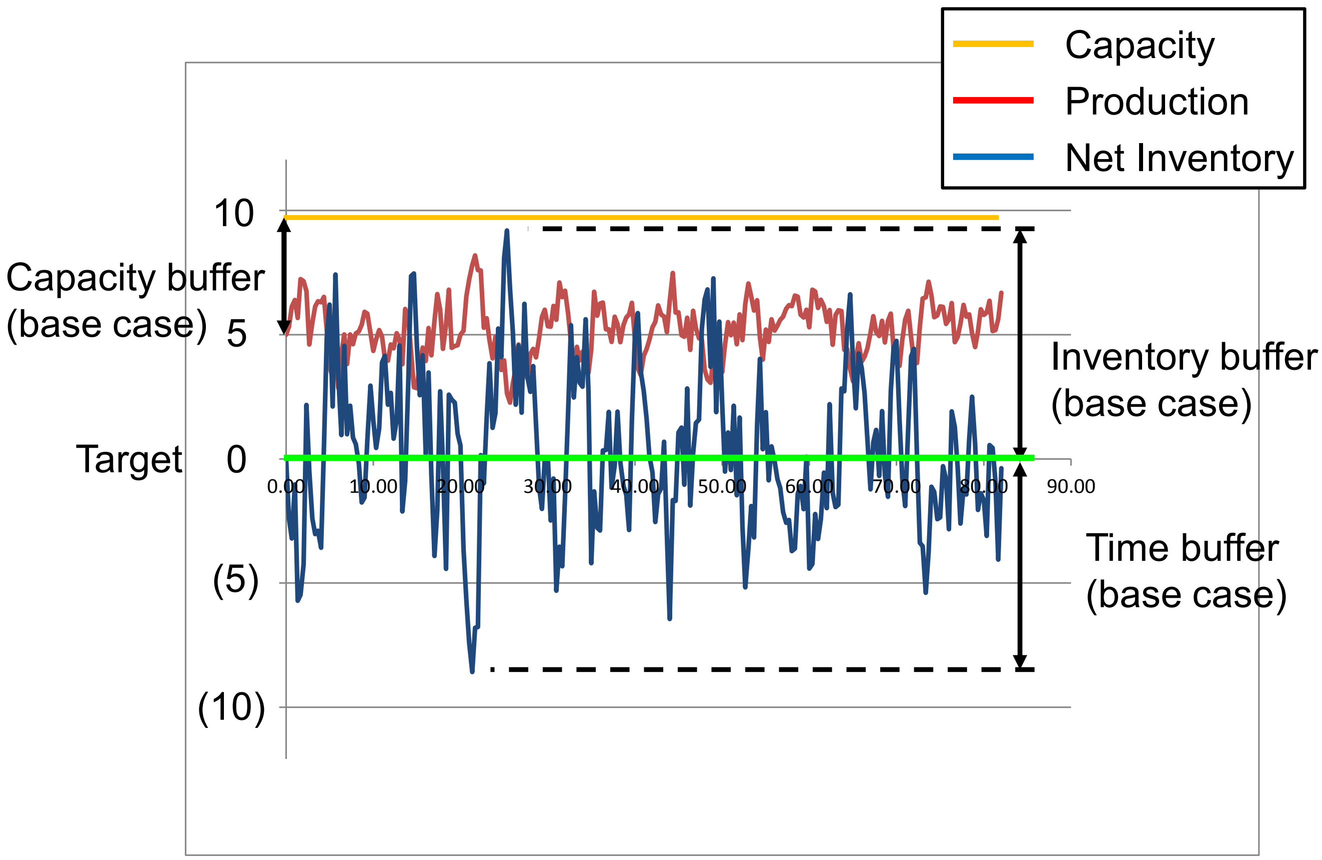


Production
= 5 – Net Inv

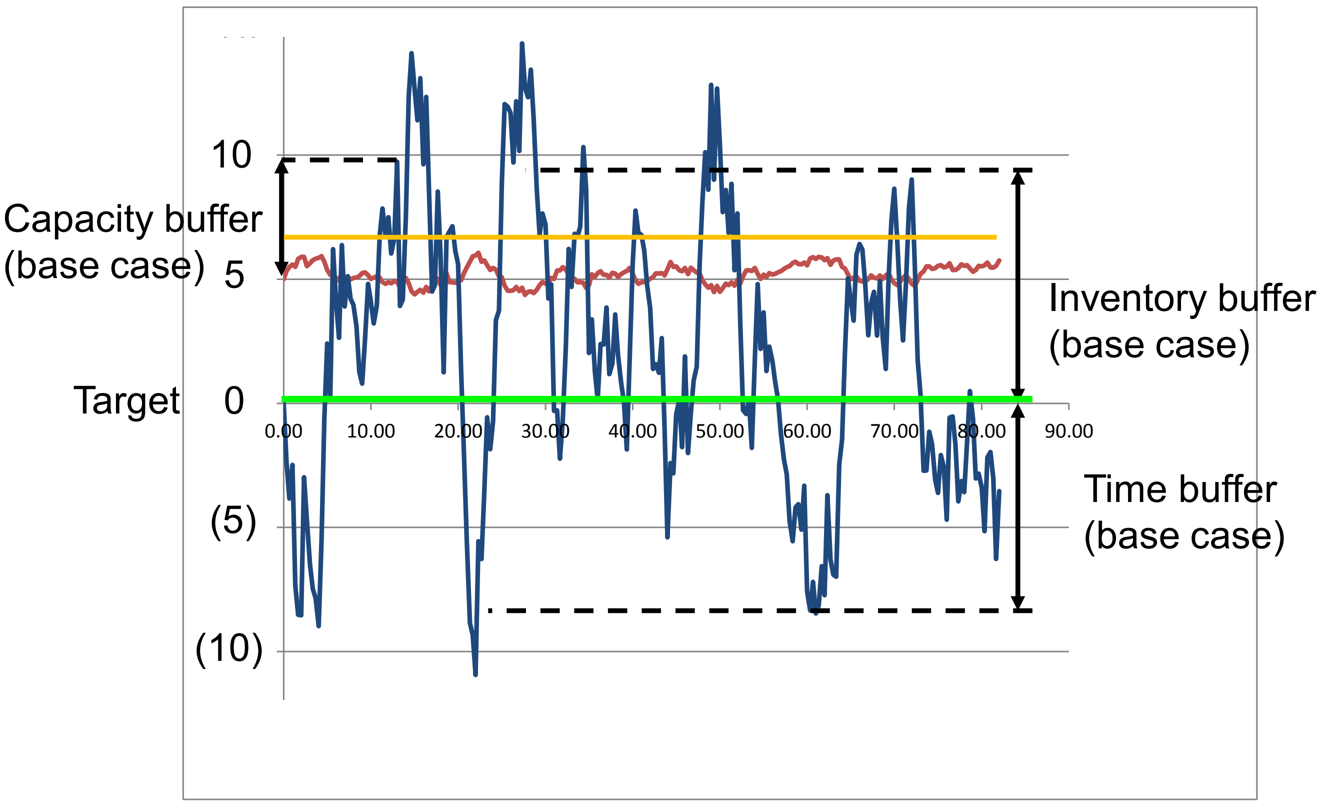
Target
Net Inv = 0

Avg Dmd = 5/day

More variability in production—Less variability in net inventory



Low variability in production—High variability in net-inventory



Buffers in Project Production

- Inventory—pre-fabrication
  - Prefab units
  - Prepare materials (e.g., rebar, etc.) before hand
- Time—quoting lead times
  - Lead time depends on current queue.
  - Average lead time will be less then using a constant lead time for same on-time delivery
- Capacity—mitigate variability
  - Recourse capacity (e.g., extra shift, weekend, overtime)
  - No recourse = delays

Application of Factory Physics Analytics

Some Basic Factory Physics Principles

- Little's Law
  - Relates basic plant performance measures

$$\text{WIP} = (\text{Cycle Time})(\text{Throughput})$$

- VUT Equation
  - Quantifies queueing effects
  - Relates variability, capacity, and time buffers

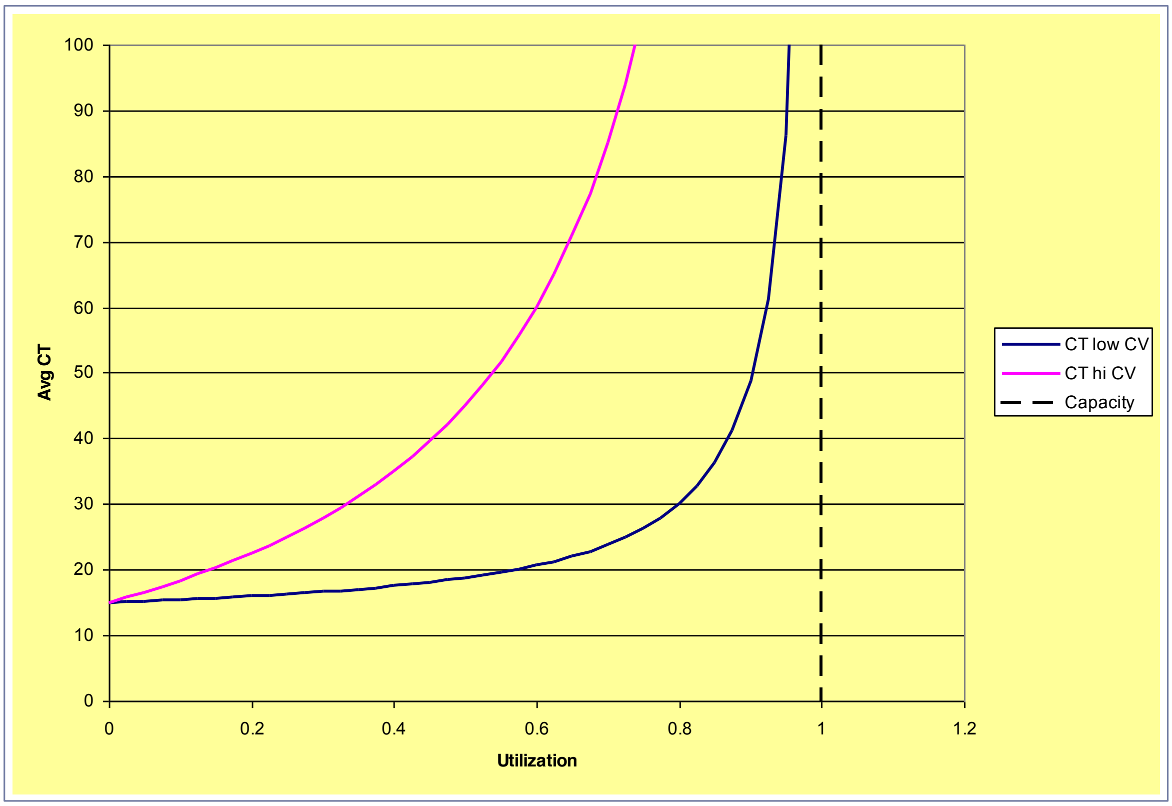
$$\text{CT}_q \approx V \times U \times t$$
$$\approx \left(\frac{c_a^2 + c_e^2}{2}\right)\left(\frac{u}{1-u}\right)t_e$$

- Variance of Replenishment Time Demand
  - Drives inventory and service
  - Accounts for variability in demand AND supply

$$\sigma^2 = t\sigma_D^2 + d^2\sigma_T^2$$

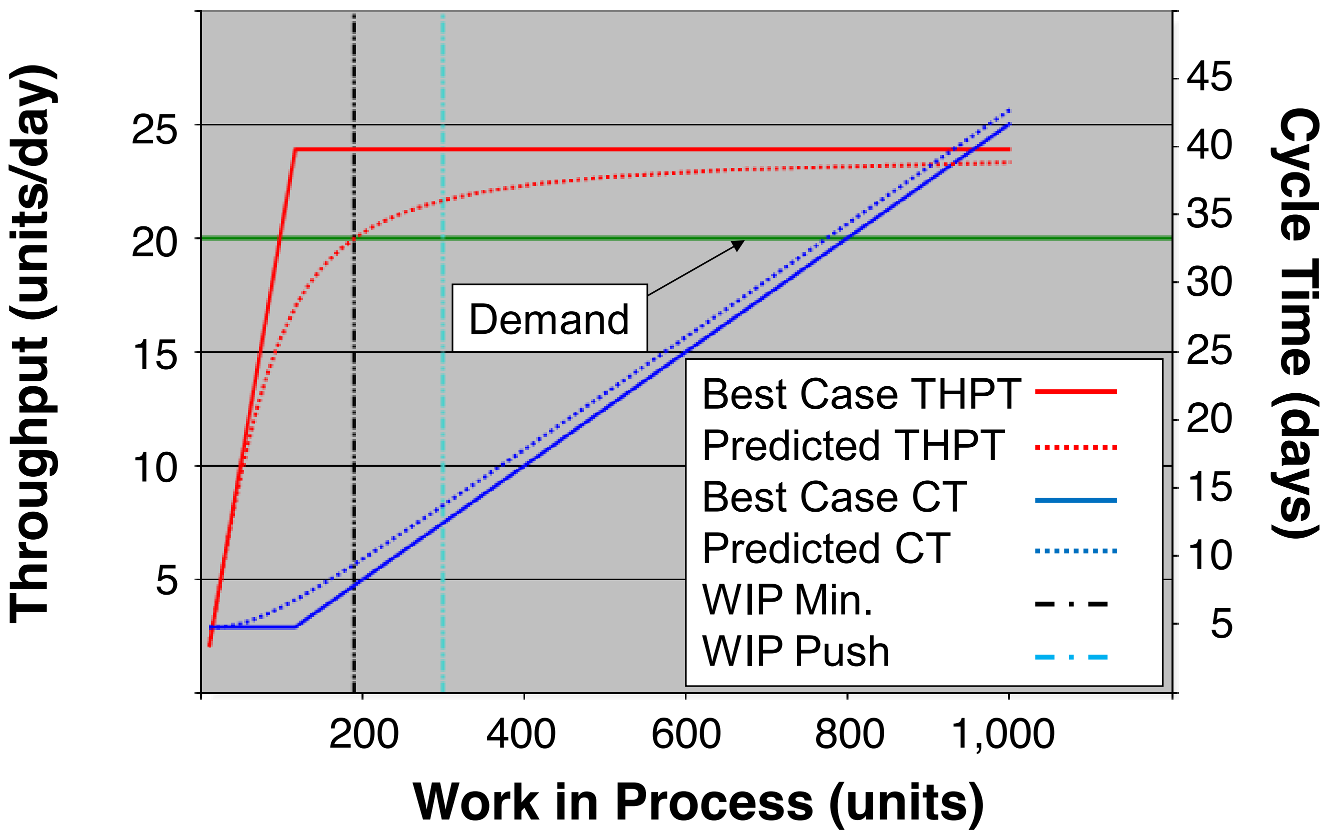
Appropriate use provides predictive control and optimal performance.

Law: Cycle time increases sharply as utilization goes to 100%



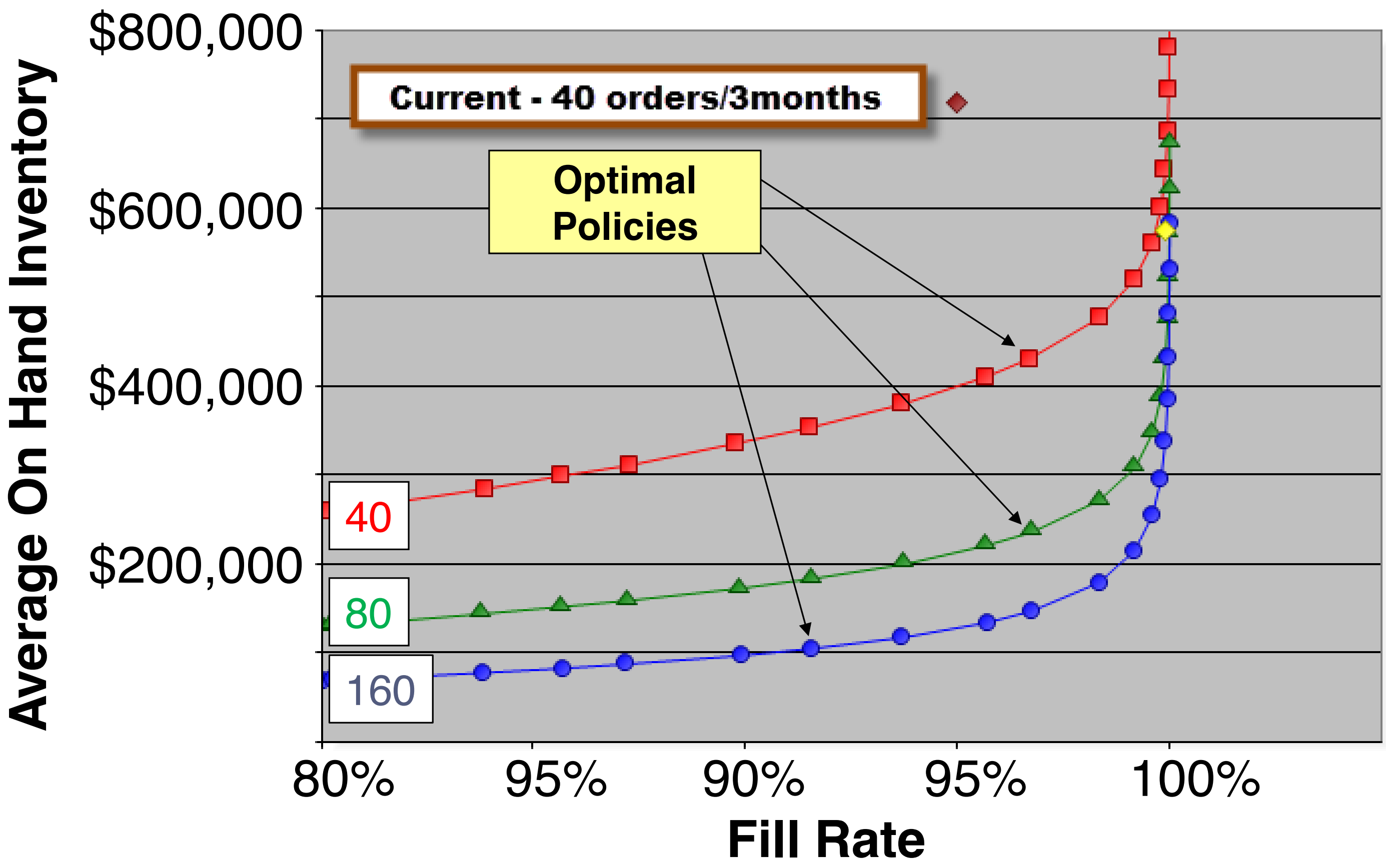
You <u>will not</u> schedule at 100% utilization over the long term.

Performance Graph for Throughput, WIP and Cycle Time

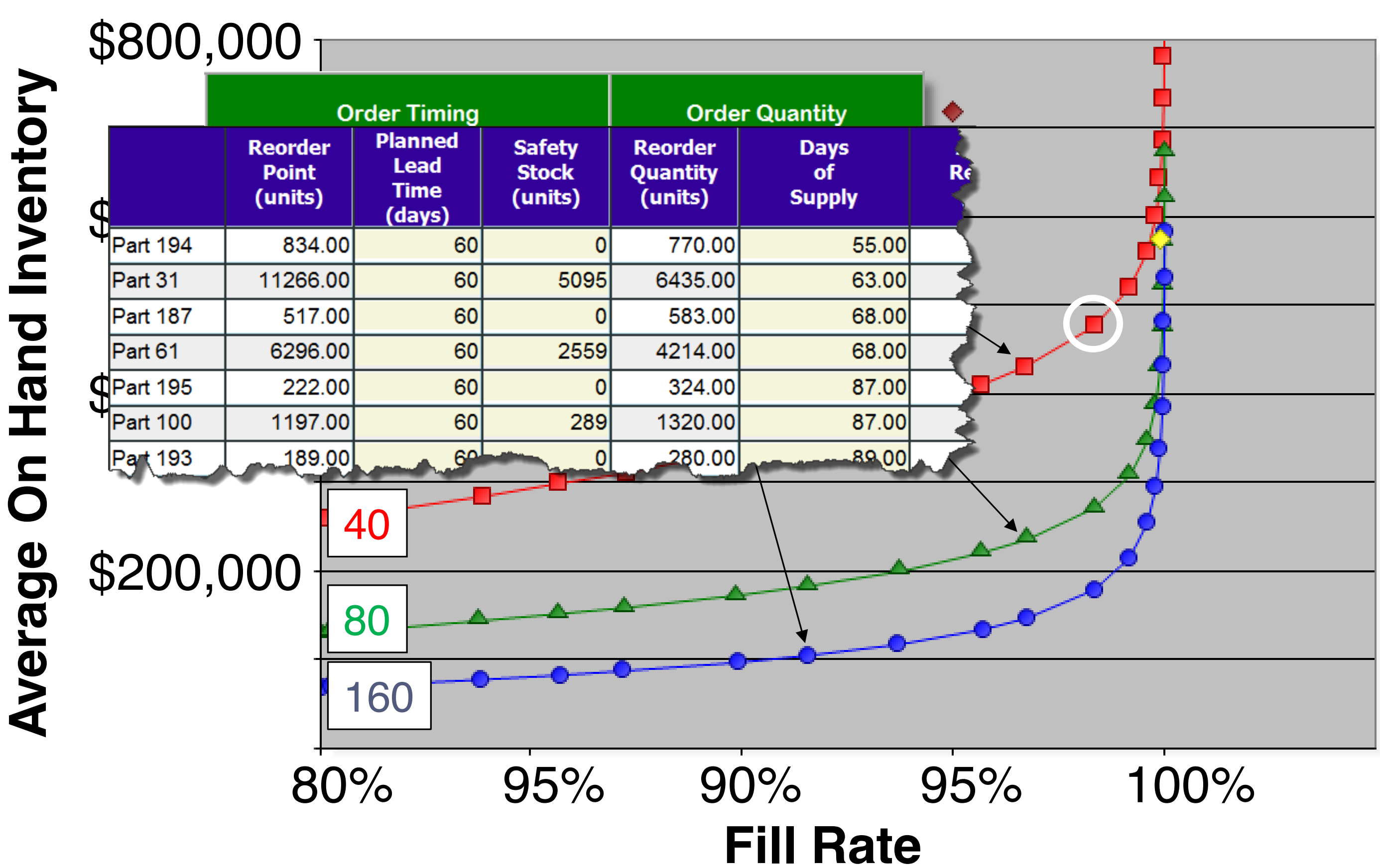


Best combination of Revenue, Working Capital, and Response Time

Efficient Frontiers for Stock



Efficient Frontiers for Stock



	Order Timing			Order Quantity		
	Reorder Point (units)	Planned Lead Time (days)	Safety Stock (units)	Reorder Quantity (units)	Days of Supply	Re
Part 194	834.00	60	0	770.00	55.00	
Part 31	11266.00	60	5095	6435.00	63.00	
Part 187	517.00	60	0	583.00	68.00	
Part 61	6296.00	60	2559	4214.00	68.00	
Part 195	222.00	60	0	324.00	87.00	
Part 100	1197.00	60	289	1320.00	87.00	
Part 193	189.00	60	0	280.00	89.00	

Set optimal RM, Kanban, and/or FG for desired customer service.

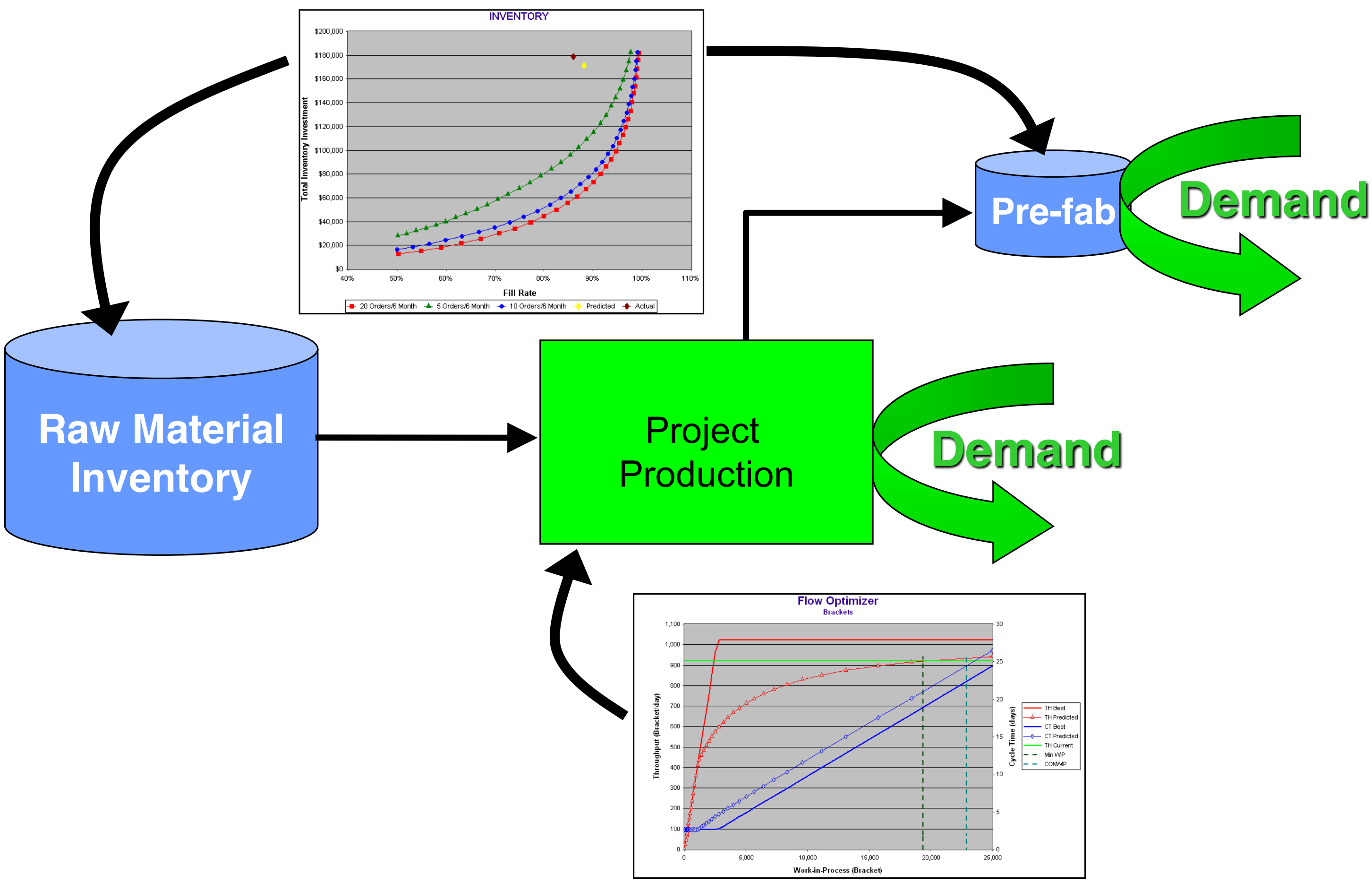
Best Possible Performance Goals

Strategy. Execution. Profit.

- Flows
  - Maximum throughput with minimum cycle time
- Stocks
  - Highest service level at minimum cost

The final measure is cash flow.

Application to Project Production



The Factory Physics approach provides complete, predictive control.

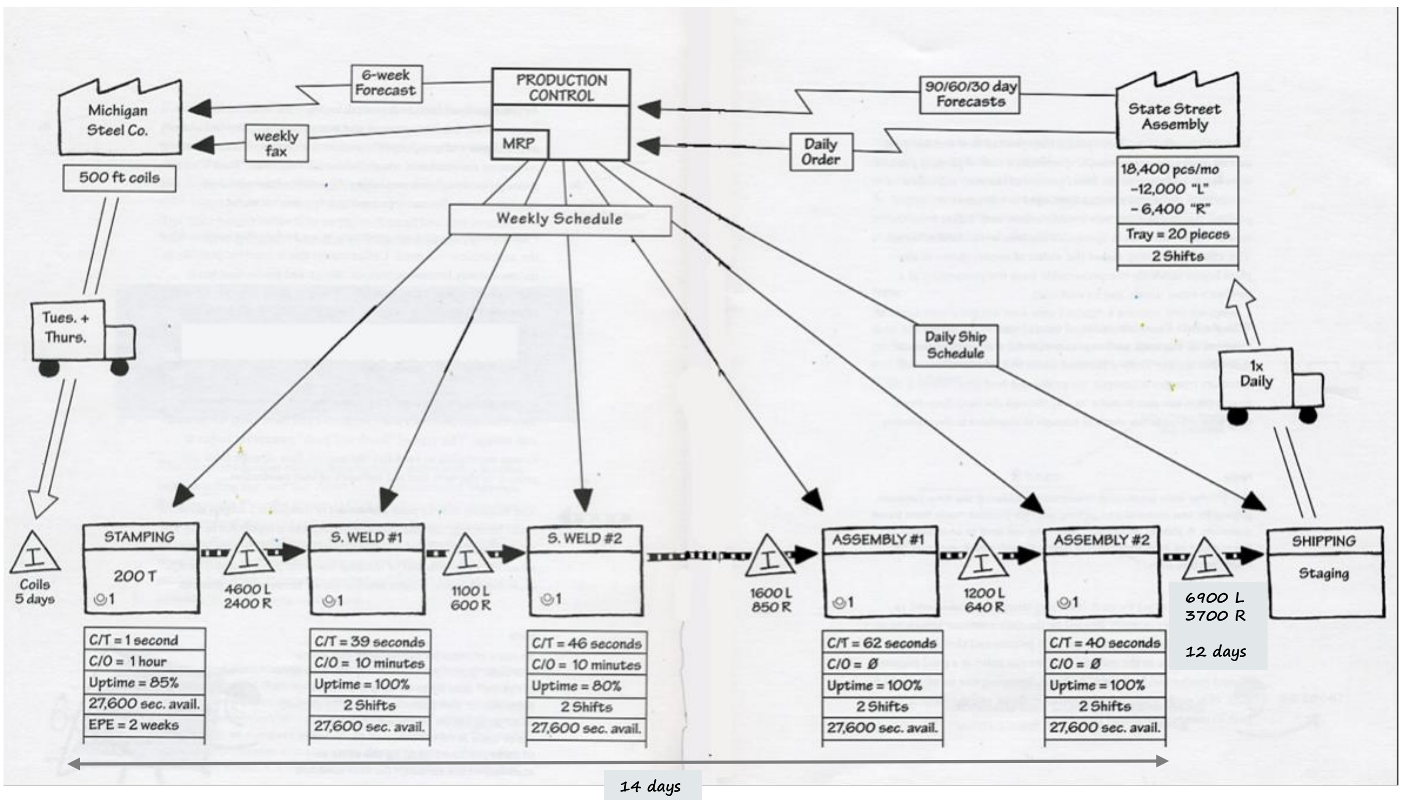
Managing Working Capital

An overview of what is possible.

Case I: *Learning to See* by Rother and Shook

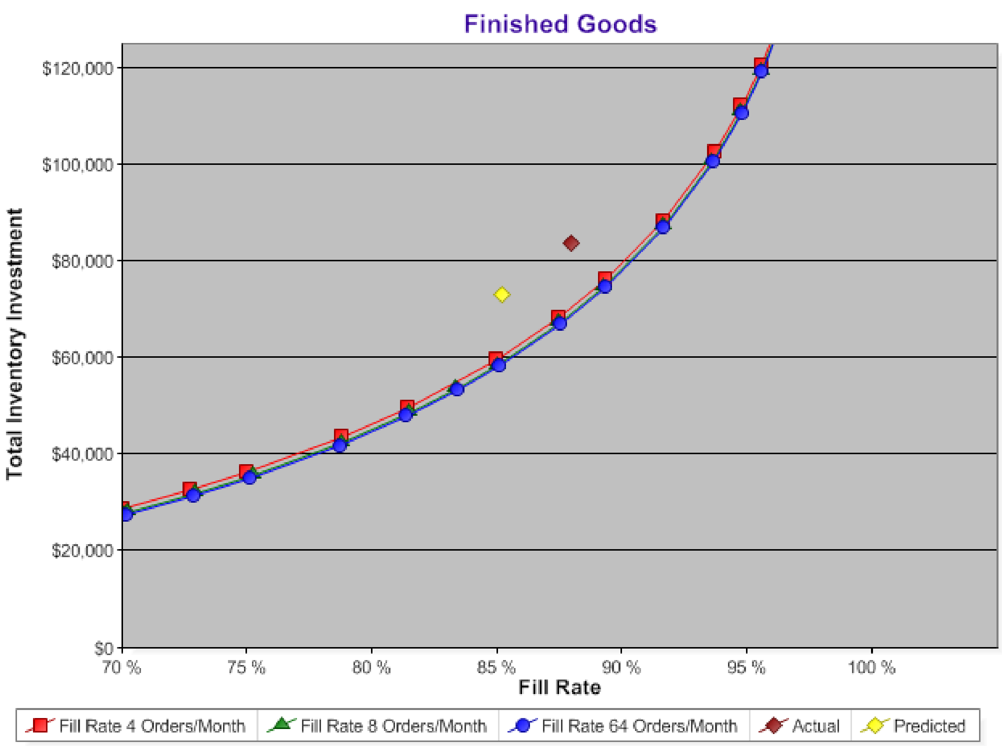
- Two Parts
  - Left Bracket $10.00
  - Right Bracket $ 1.00
- Time in system
  - Raw material 5 days
  - Work in process 14 days
  - Finished goods 12 days
- Working capital for two parts
  - Finished goods $83.5 K
  - Work in process $91.3 K
- On time delivery 88%
- ~ 1 hour per day

Current State Map

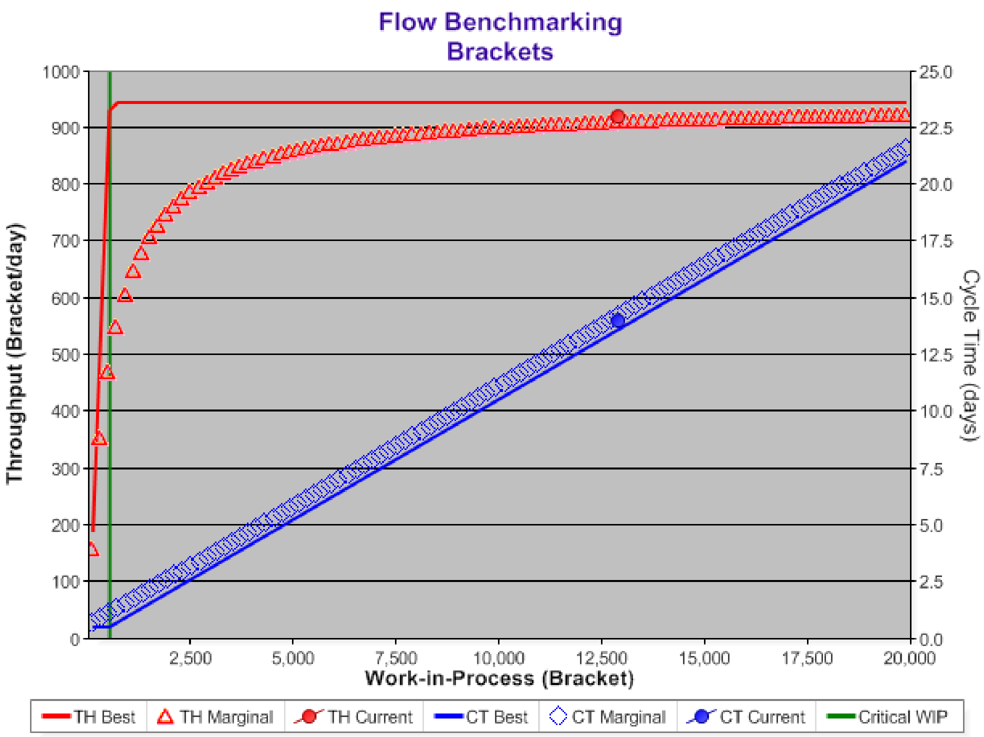


Source: Lean Enterprise Institute

Current State



Absolute Benchmarking



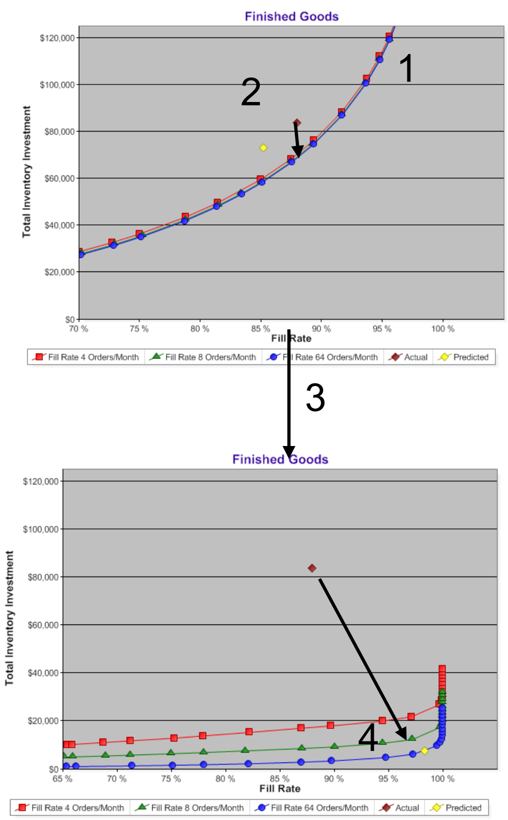
Overview of the Process

1. **Determine the efficient frontier** (i.e., min inventory investment for given service level)

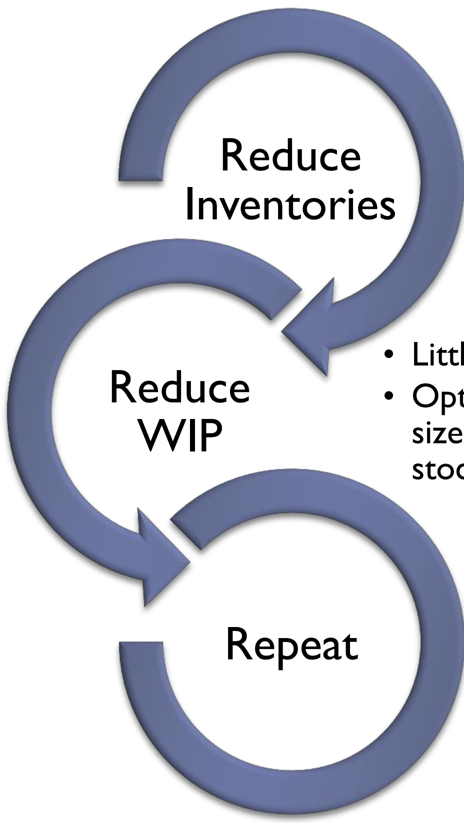
2. **Move to the frontier** by optimizing policies

3. **Move the frontier** with improvements to the operation

4. **Move to the new frontier** by re-optimizing the policies and continue



The Process

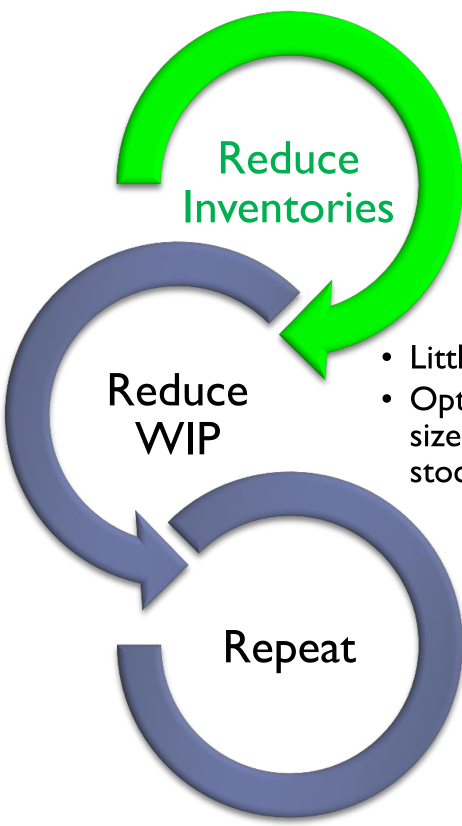


- Optimize Inventory

- Little's Law
- Optimize lot sizes, safety stocks

- Reduce variability and waste

Step 1

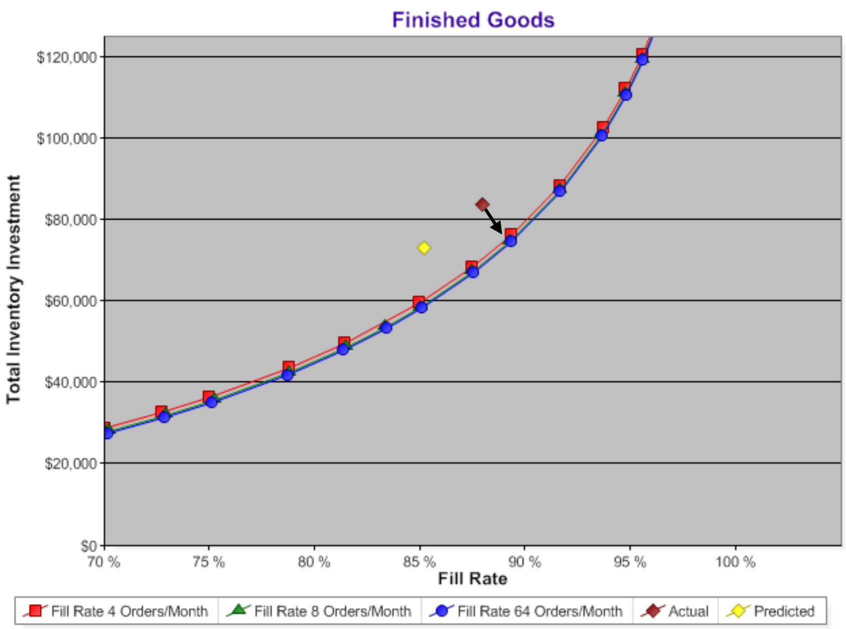


- Optimize Inventory

- Little's Law
- Optimize lot sizes, safety stocks

- Reduce variability and waste

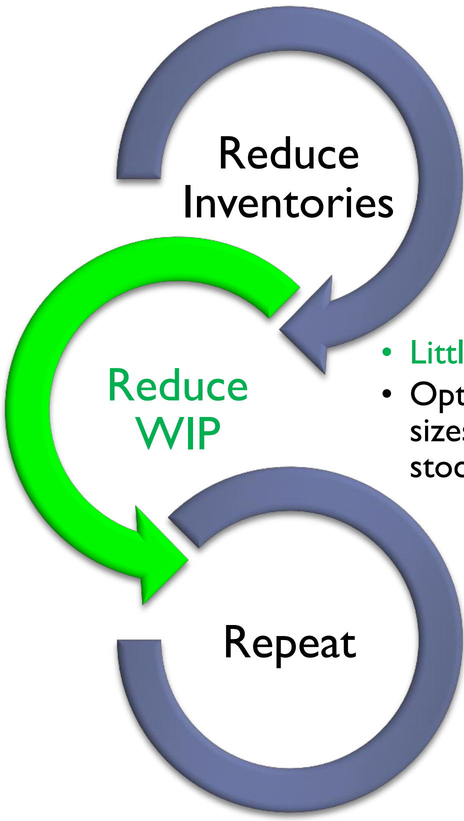
- Optimize inventory controls
- No change to environment (yet!)



Results

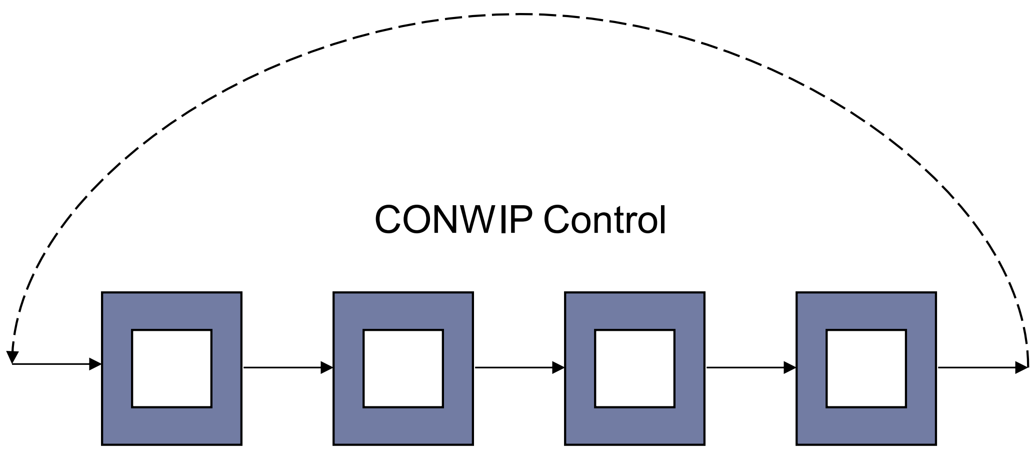
- Reduce inventory from $83.5K to $76.4K
- Increase fill rate from 88% to 89%

Step 2



- Optimize Inventory
- Little's Law
- Optimize lot sizes, safety stocks
- Reduce variability and waste

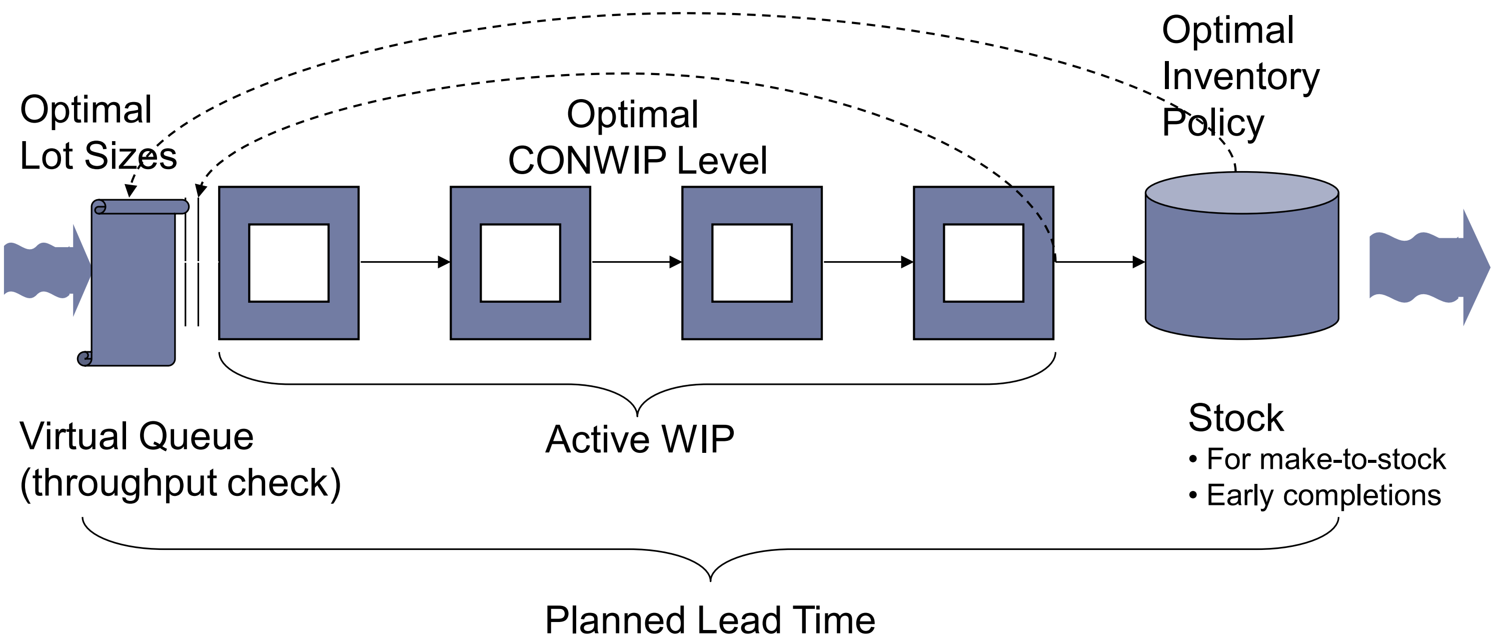
Control WIP with Little's Law



Start next job whenever WIP falls below maximum level
WIP remains mostly "constant"

CONWIP is a general pull strategy
that can be used in a high-mix environment

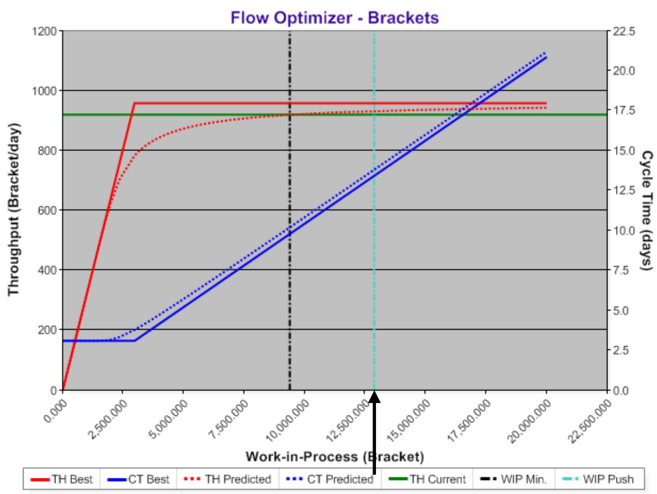
Control WIP—Check Throughput

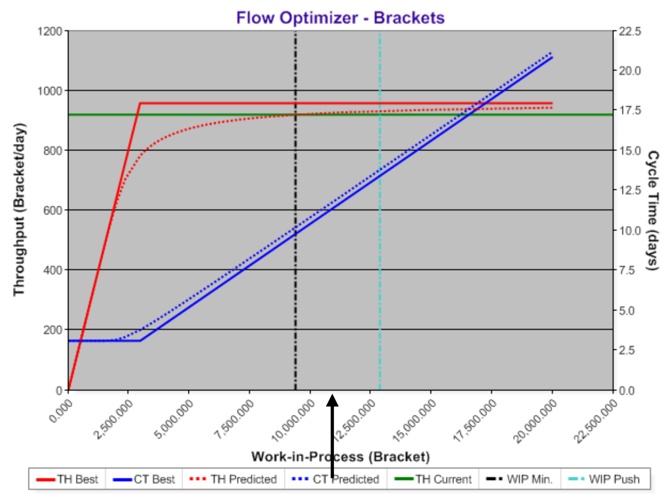


When Virtual Queue exceeds limit …
Use "recourse" capacity or push out due dates

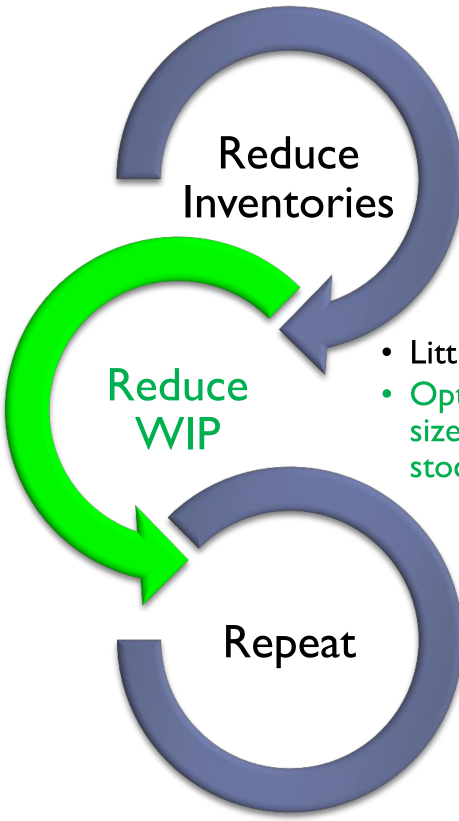
Before and after reducing WIP

Cycle time	= 14.0 days	Cycle time	= 11.9 days
WIP	= 91.3 K$	WIP	= 77.9 K$





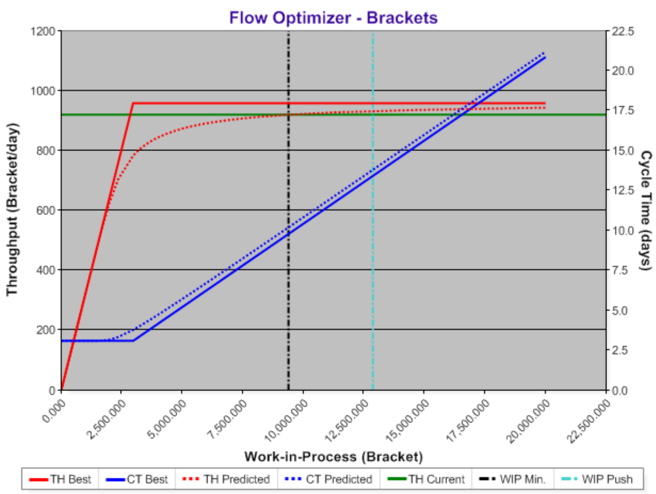
Step 2—continued

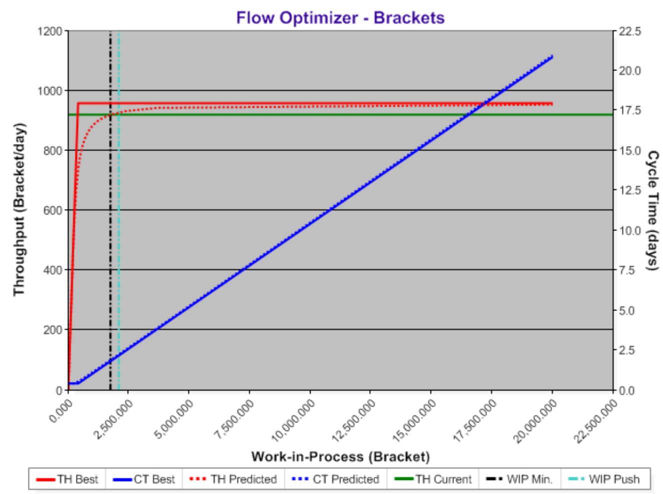


- Optimize Inventory
- Little's Law
- Optimize lot sizes, safety stocks
- Reduce variability and waste

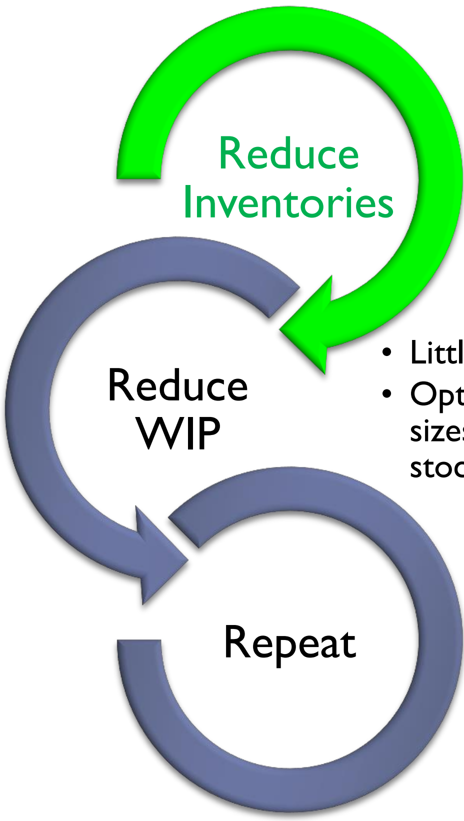
Before and after optimizing lot sizes

Cycle time	**= 11.9 days**	**Cycle time**	**= 2.7 days**
WIP	**= 77.9 K$**	**WIP**	**= 16.9 K$**





Repeat Step 1 for improved environment



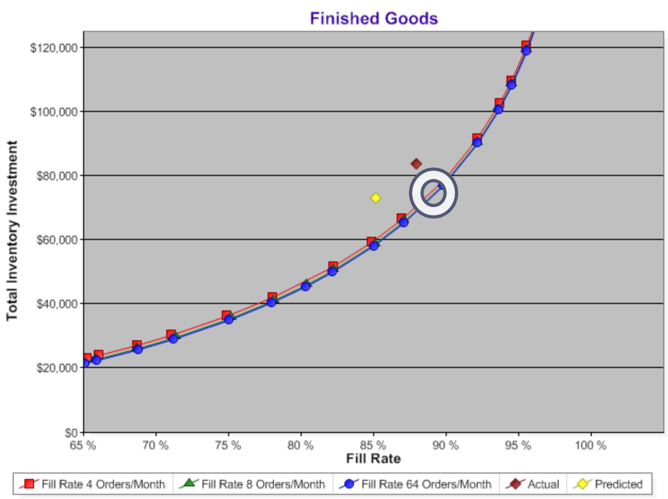
- Re-optimize Inventory

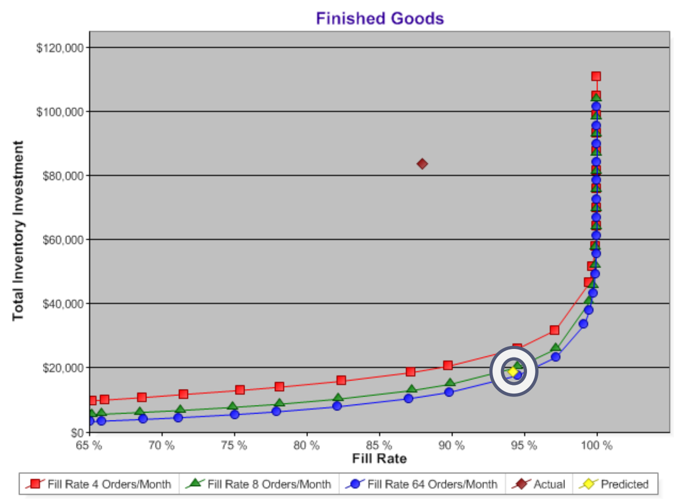
- Little's Law
- Optimize lot sizes, safety stocks

- Reduce variability and waste

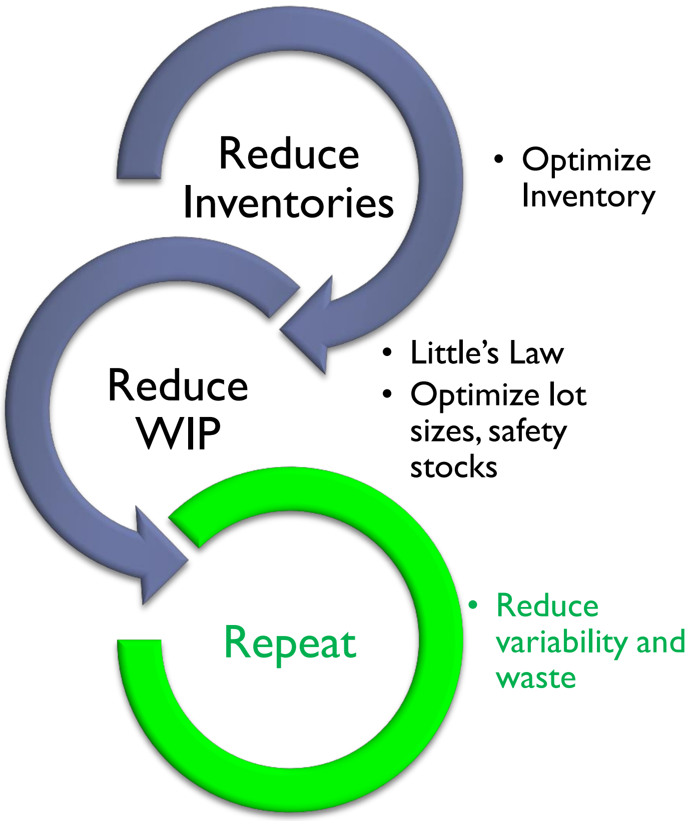
Before and after re-optimization

Fill Rate	**= 89%**	**Fill Rate**	**= 95%**
FG	**= 76.4 K$**	**FG**	**= 24.6 K$**





Step 3: Reduce variability and waste Re-optimize

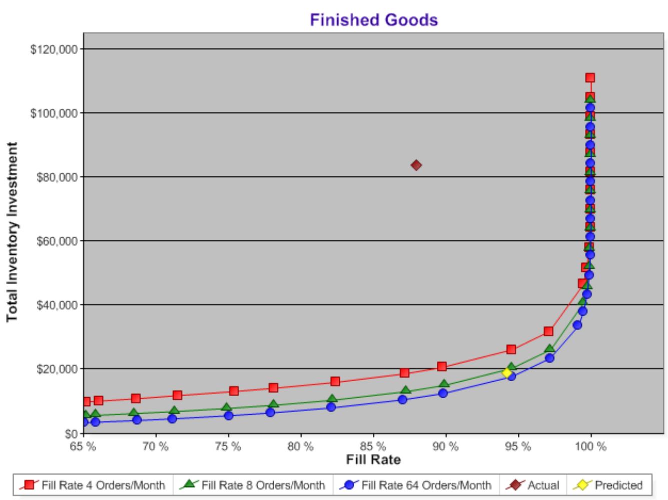


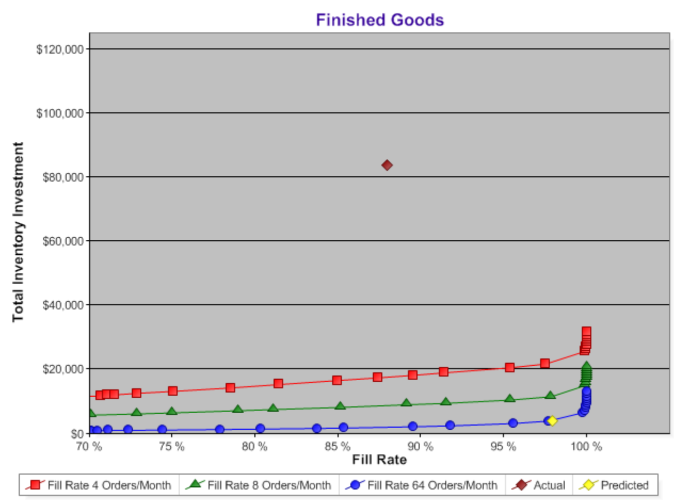
Reduce variability and waste

- Better balance of line.
- Employ standardized processes in the work place using 5S
- Reduce down time with FMEA and SMED.
- Re-optimize after improving environment

Before and after reducing variability and waste

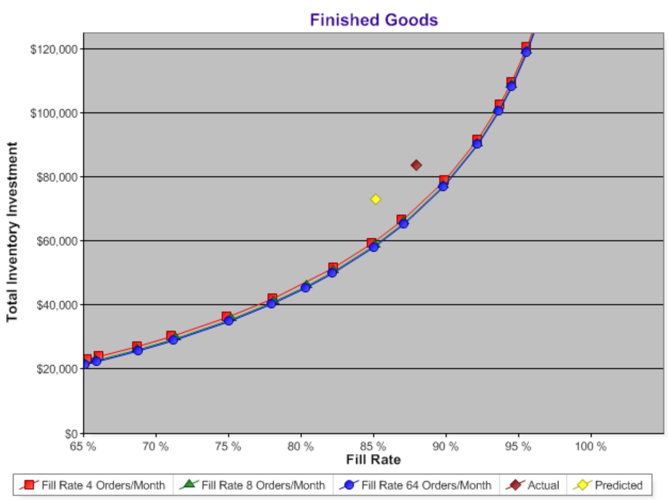
Fill Rate	**= 95.0%**	**Fill Rate**	**= 98%**
FG	**= 24.6 K$**	**FG**	**= 5.55 M$**
WIP	**= 16.9 K$**	**WIP**	**= 3.70 M$**
Cycle time	**= 2.7 days**	**Cycle time**	**= 0.60 days**

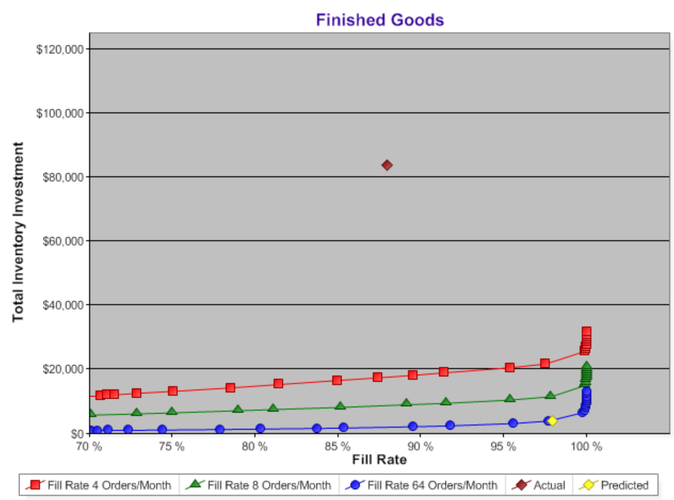




Initial and Final States

Fill Rate	**= 88%**	**Fill Rate**	**= 98%**
FG	**= 83.5 K$**	**FG**	**= 5.55 K$**
WIP	**= 91.3 K$**	**WIP**	**= 3.70 K$**
Cycle time	**= 14 days**	**Cycle time**	**= 0.60 days**





Eliminated all overtime.

Conclusions

- The improvements were dramatic
- The improvements were the result of changing both
  - The policies (larger improvements) and
  - The environment (smaller improvements)
- Lean and Six Sigma focus on the environment
- Factory Physics methods can optimize policies and identify improvement opportunities in the environment