

Lean Construction & Design

Robert Warcup, PhD



What About Rob?...

- Assistant super, Estimator, Purchasing – 2001 (Intro to Lean – 2007)
- Member of Lean Construction and Design Association
- Associate Professor of Construction Management at Utah Valley University
- PhD in Technology and Engineering Education
 - Dissertation: Lean Construction and Company Culture
- AGC/NAHB Lean Construction Instructor
- Lean Trainer & Consultant for Local and National Construction Firms
- **LEAN NERD!**



4 Presentation Sections

1. 8 Lean Wastes
2. Value Stream Mapping
3. Last Planner System
4. Lean Design



Teaching Lean

1. Identify current industry problems
2. Show how lean mitigates those problems

Too often we accept problems because we don't take time to solve them.



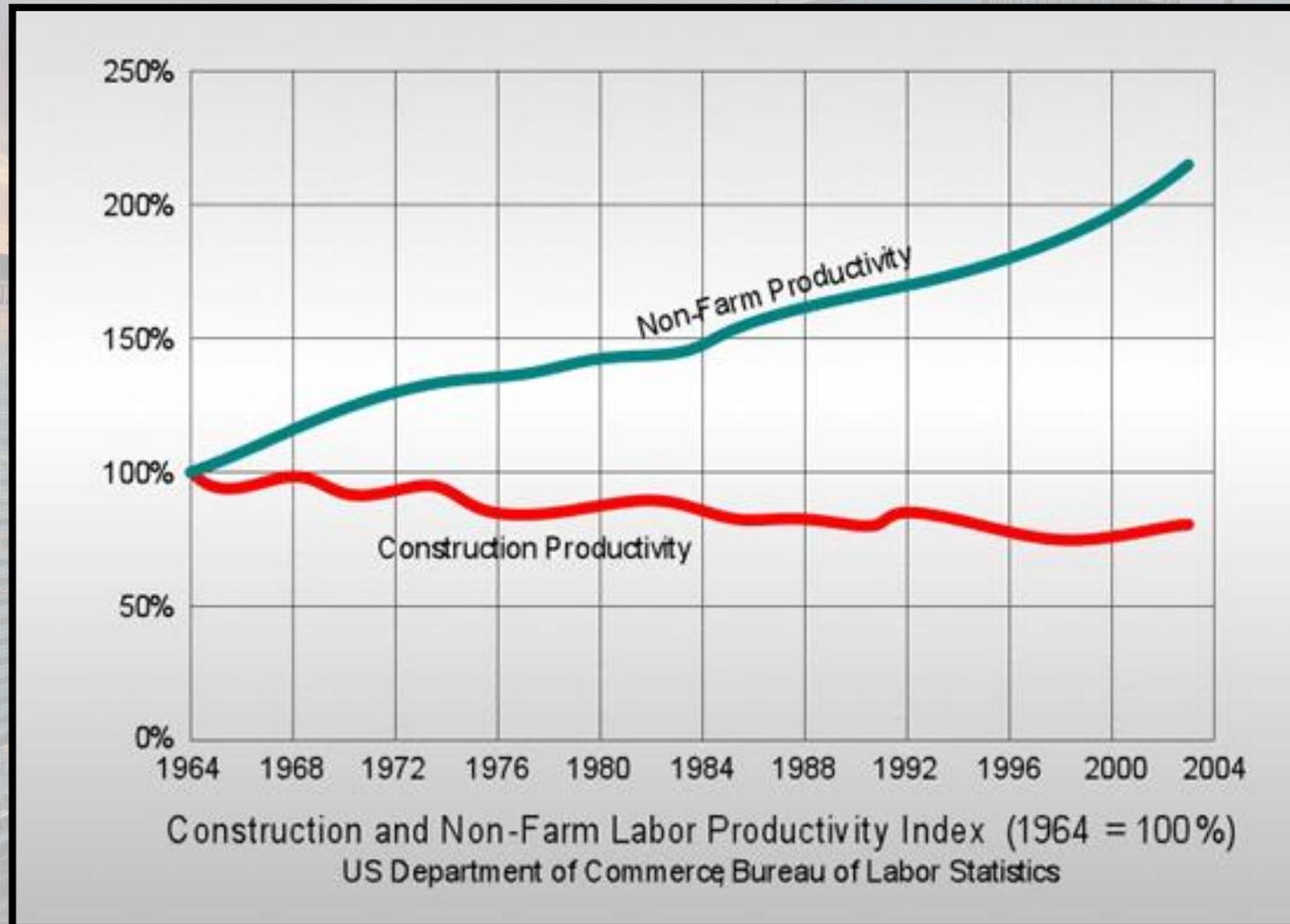
An aerial photograph of a city at dusk or dawn. In the foreground, a construction site is visible with several yellow cranes and buildings under construction. In the background, a dense urban landscape with various buildings is visible under a cloudy sky. A large, modern glass skyscraper is prominent on the right side of the image, partially obscured by a semi-transparent white box containing text.

Storytelling with the

8 Lean Wastes

Lean 101

Construction Productivity Decline



Meet Butch

- Seasoned commercial super
- Current Project:
 - High School
- Favorite phrase:
 - “I’ve been doing it this way for 35 years!”



8 Wastes of Lean (Lean 101)

To remember The 8 Wastes, you can use the acronym "DOWNTIME."

| | | | | | |
|----------|----------------------------|--|---|--|--|
| D | Defects |  |  |  |  |
| O | Overproduction | Defects | Overproduction | Waiting | Non-Utilized Talent |
| W | Waiting | Efforts caused by rework, scrap, and incorrect information. | Production that is more than needed or before it is needed. | Wasted time waiting for the next step in a process. | Underutilizing people's talents, skills, & knowledge. |
| N | Non-Utilized Talent | | | | |
| T | Transportation |  |  |  |  |
| I | Inventory | Transportation | Inventory | Motion | Extra-Processing |
| M | Motion | Unnecessary movements of products & materials. | Excess products and materials not being processed. | Unnecessary movements by people (e.g., walking). | More work or higher quality than is required by the customer. |
| E | Extra-Processing | | | | |

Butch doesn't know anything about lean or the 8 wastes.

BUT, he has LOTS of EXPERIENCE...

Source: Lean6sigma4all.eu

Metal Door Frames

- 152 Door frames delivered in “bundles” during steel erection
- Delivered during steel erection (early - just to be safe)
- Cost: \$210/Frame (152 x \$210 = \$31,920.00)
- **WASTE = INVENTORY**



8 Lean Wastes

1. Inventory

\$0.00

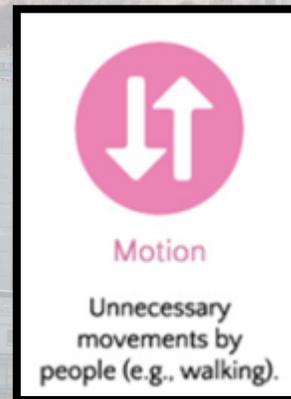
However...

TOTAL

\$0.00

Because the doors came so early...

- The door frames got in the way of production operations
- All 152 Door frames had to be separated & moved BY HAND into a storage container
- Cost: 3 laborers @ \$21 ea. for 4.5 hrs = $(3 \times \$21 \times 4.5) = \283.50
- **WASTE = MOTION**



8 Wastes

- | | |
|-----------------------|----------|
| 1. Inventory (frames) | \$0.00 |
| 2. Motion | \$283.50 |

Not too bad... right?

TOTAL

\$283.50

8 Wastes are Analyzed from the Owner's Perspective

- Is the waste of motion creating value for the Utah DFCM?



- Would the DFCM be willing to pay extra for the waste?

In the process of moving the doors...

- 11 doors were damaged
- **WASTE = DEFECT/DAMAGE**
- 6 of those doors were repaired (1 carpenter @ \$27/hr x 5 hrs = \$135.00)
- **WASTE = EXTRA PROCESSING**
- 5 new doors had to be re-ordered (5 doors x \$210 ea. = \$1050.00)
- **WASTE = INVENTORY**



Defects

Efforts caused by rework, scrap, and incorrect information.



Extra-Processing

More work or higher quality than is required by the customer.



Inventory

Excess products and materials not being processed.

8 Wastes

| | |
|-----------------------------|------------------------------|
| 1. Inventory (extra frames) | \$1050.00 |
| 2. Motion | \$283.50 |
| 3. Defect/Damage | \$0.00 (caused other wastes) |
| 4. Extra-Processing | \$135.00 |

It get's worse...

| | |
|--------------|------------------|
| TOTAL | \$1468.50 |
|--------------|------------------|

More Wastes...

- Project Engineer spent 1 hr ordering new door frames (\$32.00)
- **WASTE = EXTRA-PROCESSING**
- Carpenter installers moved frames to construction install area
- **WASTE = NON-UTILIZED TALENT** (opportunity cost)
- New doors were delivered to the site. (\$82.00)
- **WASTE = TRANSPORTATION**
- **WASTE = WAITING**



Extra-Processing

More work or higher quality than is required by the customer.



Non-Utilized Talent

Underutilizing people's talents, skills, & knowledge.



Transportation

Unnecessary movements of products & materials.



Waiting

Wasted time waiting for the next step in a process.

8 Wastes

| | |
|-----------------------------|-----------|
| 1. Inventory (extra frames) | \$1050.00 |
| 2. Motion | \$283.50 |
| 3. Defect/Damage | \$0.00 |
| 4. Extra-Processing | \$182.00 |
| 5. Non-Utilized Talent | \$0.00 |
| 6. Transportation | \$82.00 |
| 7. Waiting | \$0.00 |

TOTAL **\$1597.00**

Stop the
Bleeding!

We're NOT Done Yet!

- Because the installers didn't have frames to install per the schedule, they began other tasks early; installing door slabs, hardware, etc. even though the schedule didn't require it for 20 more days.

- **WASTE = OVERPRODUCTION**

- **Wait! Getting ahead is good, right?**

- As construction continued, several door slabs were damaged and several handle sets were broken. (\$2,340.00 moving out damaged doors, fixing dents, ordering/processing new handle sets, delivering new inventory, etc.)

- **WASTE = NON-UTILIZED TALENT** (carpenters, super, project engineer, etc.)



8 Wastes

| | |
|------------------------|------------------|
| 1. Inventory (frames) | \$1050.00 |
| 2. Motion | \$283.50 |
| 3. Defect/Damage | \$0.00 |
| 4. Extra-Processing | \$182.00 |
| 5. Non-Utilized Talent | \$2340.00 |
| 6. Transportation | \$82.00 |
| 7. Waiting | \$0.00 |
| 8. Overproduction | \$0.00 |
| TOTAL | \$3937.50 |

Original cost of frames:
\$31920.00

Waste = 12.3% unplanned
costs in door cost code

Why? Just because Butch
ordered door frames early.

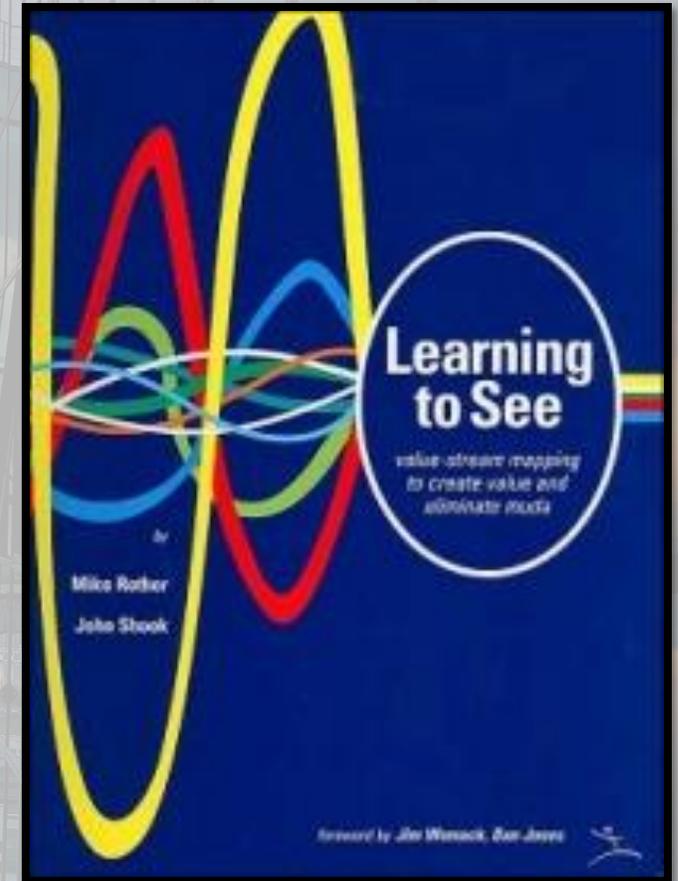
Ouch Butch!



**#!&\$#@!,
That's only ONE
Cost Code!**

The Problem of Waste

- How often does this happen?
 - All the time
 - CM, FM, Supply Chain, Design, etc.
- Why does it happen?
 - We haven't **learned to see** waste
- What can be done?
 - Lean thinking provides many answers



- By Mike Rother
- Lean Enterprise Institute
(Manufacturing)

How many of the 8 wastes can you identify?

- ✓ Defects
- ✓ **Overproduction**
- ✓ Waiting
- ✓ Non-utilized talent
- ✓ Transportation
- ✓ **Inventory**
- ✓ Motion
- ✓ Extra-processing



Paul Akers: 2 Second Lean (Lean Manufacturing Book)

<https://www.youtube.com/watch?v=wqdl6khs0uM> – Window Install – 2:15

<https://www.youtube.com/watch?v=LxMlvkeW97s> – Loader – 4:11

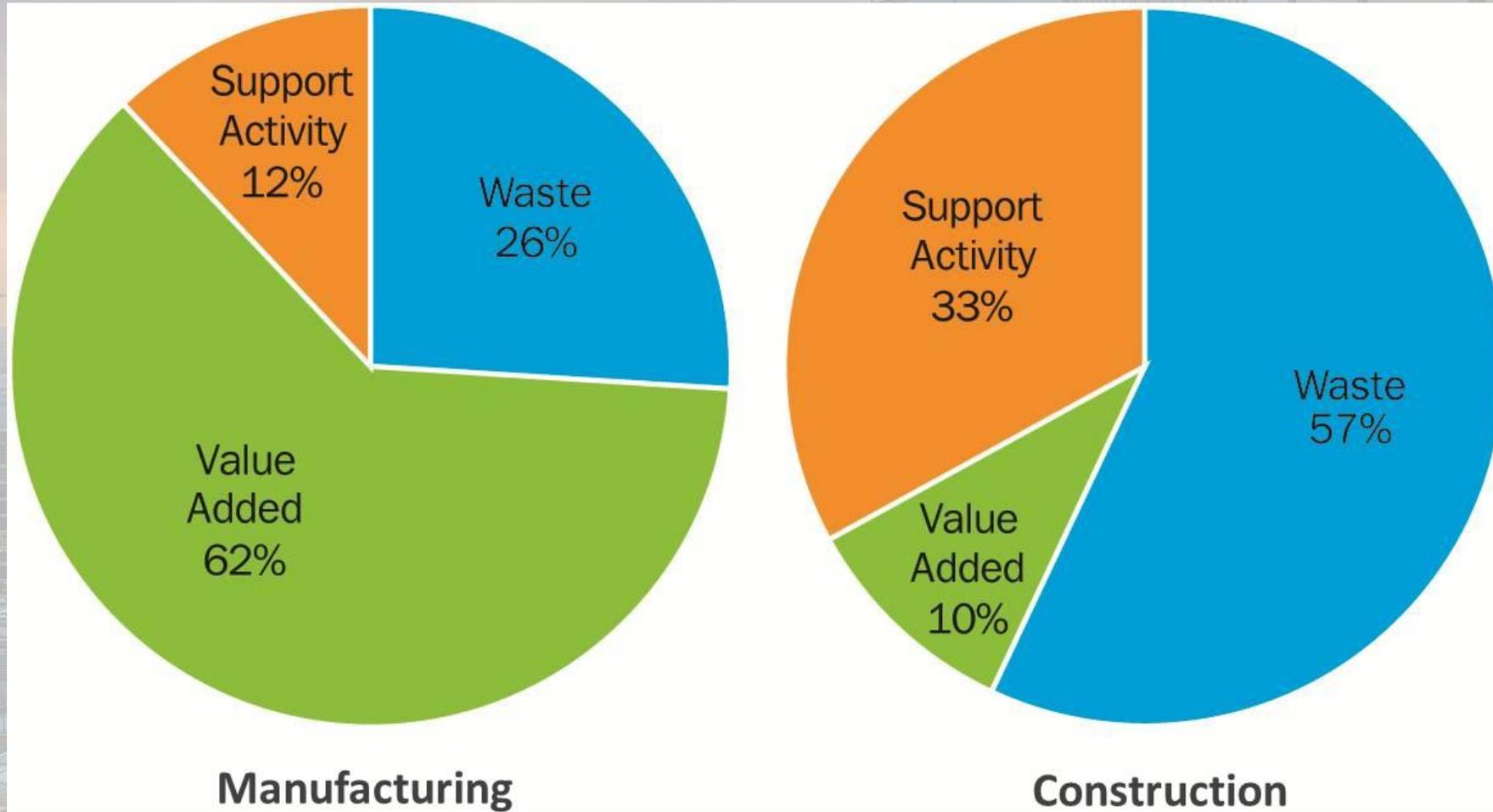
Isn't that just the cost of doing business?

- When Designers and Constructors can't see waste, they can't stop it
- Therefore, It's passed on to the owner
 - Excessive (built-in, hidden) costs
 - Poor designs (systems, plan layouts, etc.)
 - Change orders
 - Errors & poor quality
 - Warranty requests
 - Litigation

NO

How much waste are we talking about?

Source: Construction Industry Institute



Examples of Construction Waste

The cost of waste is ultimately passed on to the owner

- Extra trip charges
- Uncertainty (causes delays, mistakes)
- Negative management
- Schedule variance
- Change orders
- RFI's
- Punch lists
- Value Engineering (design)
- Warranty call – service down (FM)

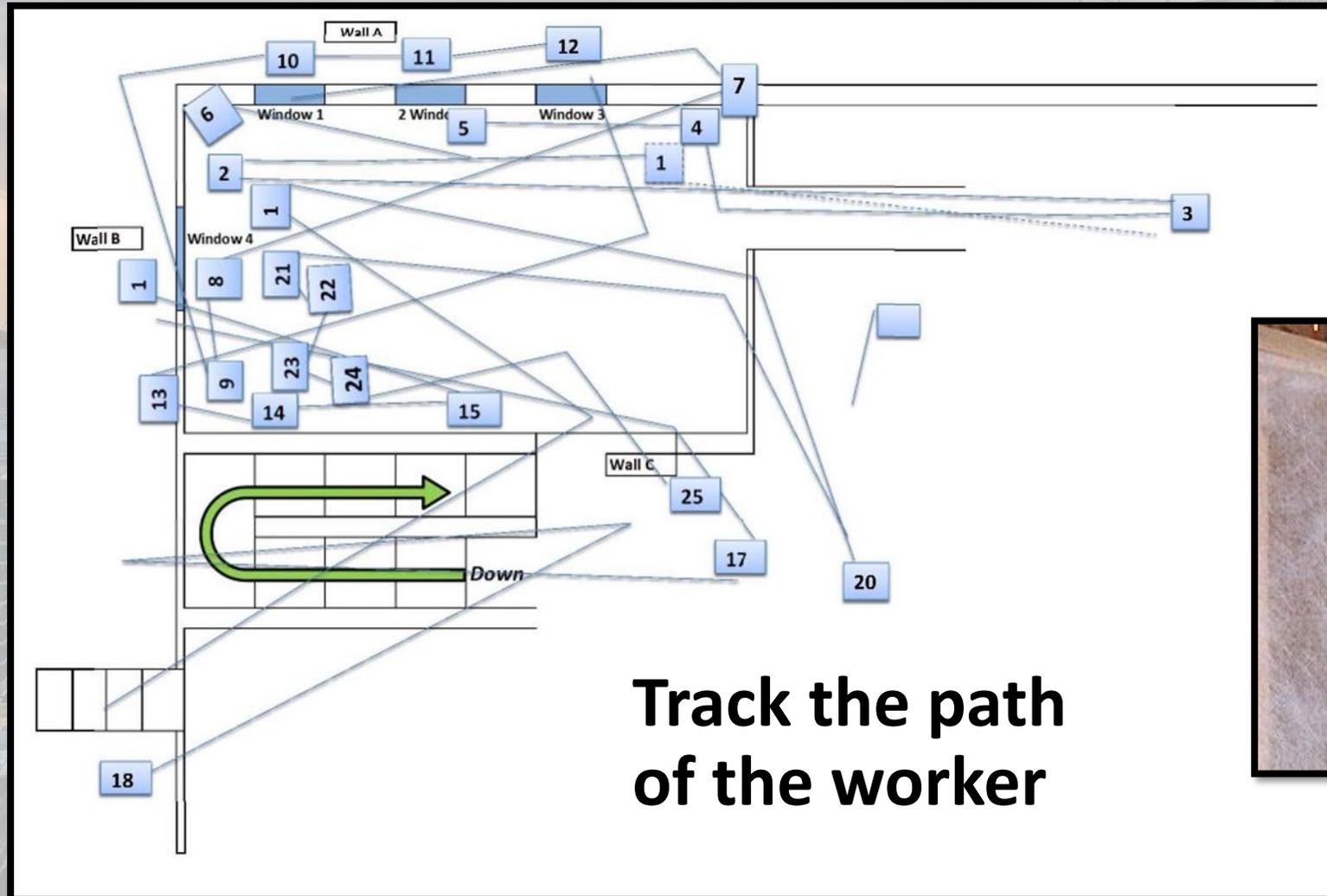


What's In It For Me?

WHY?

- **Owners:**
 - Savings
 - Increased Value
- **GC, Sub, Designers:**
 - Decreased Costs
 - Increased Profits
 - Improved Quality
 - Shorter Schedules
- **Employees (field, office):**
 - Smoother Projects
 - Less Fire-Fighting
 - Potential Promotions
 - Recognition

Spaghetti Diagram (Step 1)



**Track the path
of the worker**

**Observation Activity:
Insulation Prep**



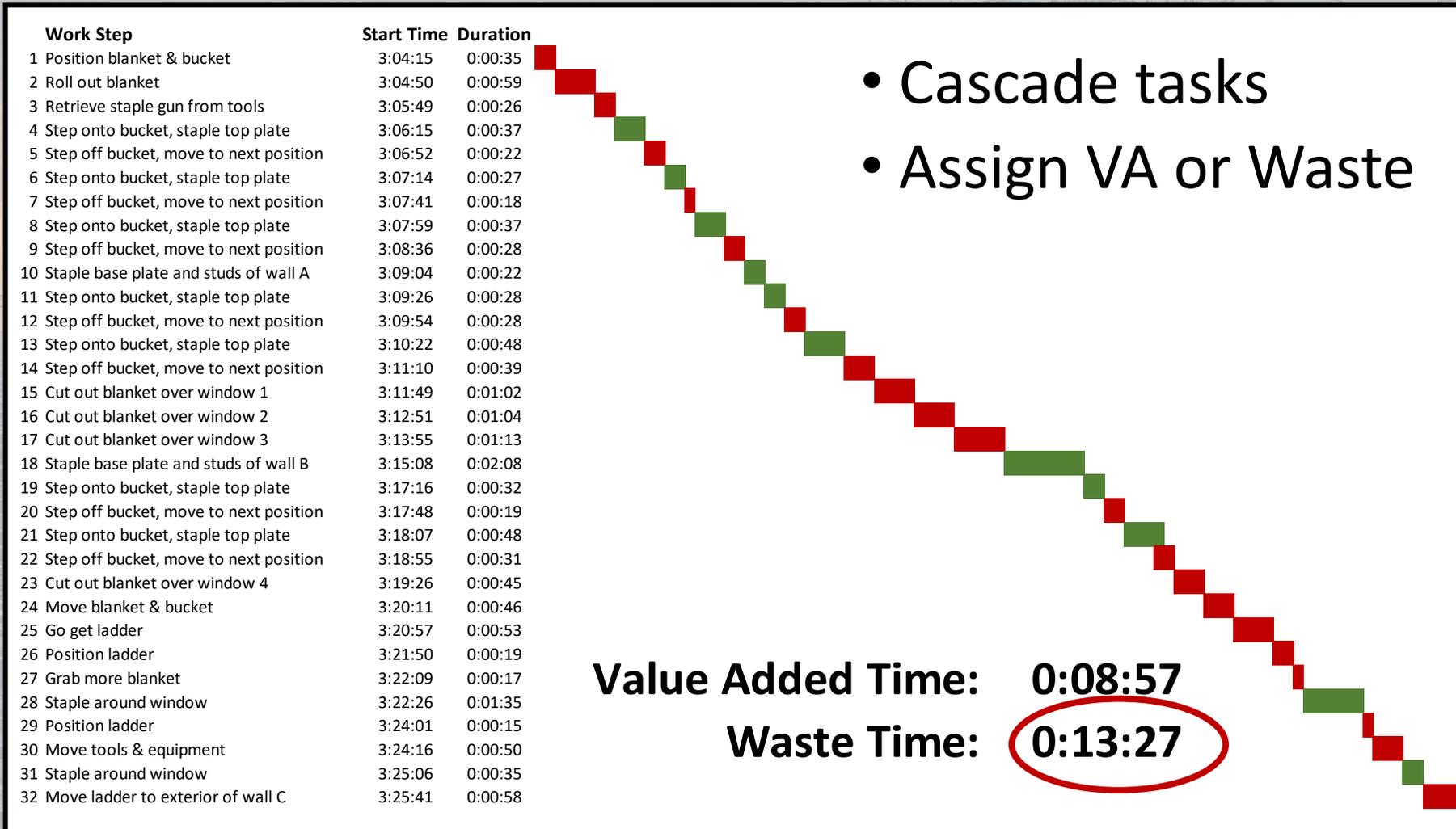
Spaghetti Diagram (Step 2)

| Work Step | Start Time |
|---|------------|
| 1 Position blanket & bucket | 3:04:15 |
| 2 Roll out blanket | 3:04:50 |
| 3 Retrieve staple gun from tools | 3:05:49 |
| 4 Step onto bucket, staple top plate | 3:06:15 |
| 5 Step off bucket, move to next position | 3:06:52 |
| 6 Step onto bucket, staple top plate | 3:07:14 |
| 7 Step off bucket, move to next position | 3:07:41 |
| 8 Step onto bucket, staple top plate | 3:07:59 |
| 9 Step off bucket, move to next position | 3:08:36 |
| 10 Staple base plate and studs of wall A | 3:09:04 |
| 11 Step onto bucket, staple top plate | 3:09:26 |
| 12 Step off bucket, move to next position | 3:09:54 |
| 13 Step onto bucket, staple top plate | 3:10:22 |
| 14 Step off bucket, move to next position | 3:11:10 |
| 15 Cut out blanket over window 1 | 3:11:49 |
| 16 Cut out blanket over window 2 | 3:12:51 |
| 17 Cut out blanket over window 3 | 3:13:55 |
| 18 Staple base plate and studs of wall B | 3:15:08 |
| 19 Step onto bucket, staple top plate | 3:17:16 |
| 20 Step off bucket, move to next position | 3:17:48 |

List the step-by-step process with time



Spaghetti Diagram (Step 3)



Spaghetti Diagram (Step 4)

Optimize the Process!

- Analyze
- Brainstorm
- Eliminate

What is Waste Elimination?



What does "Lean" mean anyway?

- Management Strategy/Philosophy/Approach
- Superior to traditional management strategies
- Lean Concepts: Value vs. Waste, Pull vs. Push

- My Lean Results:
 - 13% reduced costs
 - 40% shortened schedules
 - Improved quality
 - Improved employee morale



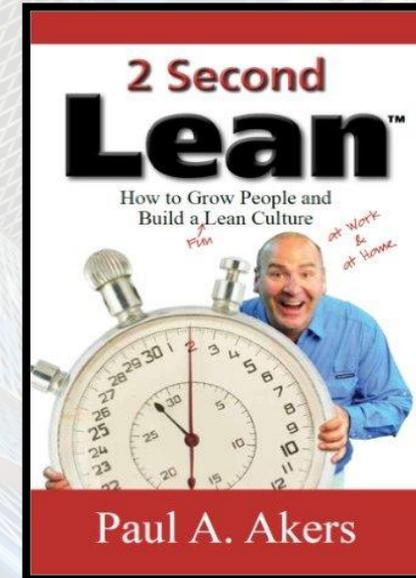
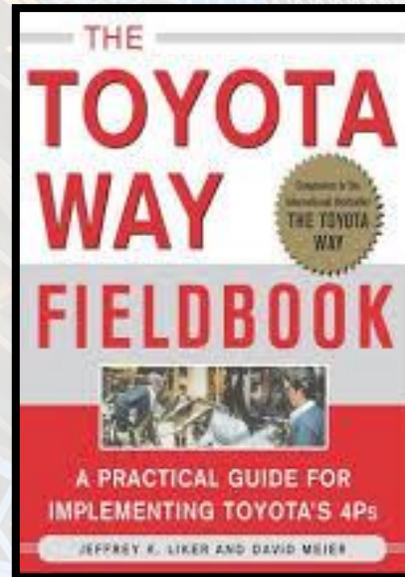
**Rob's
"Selfie"**



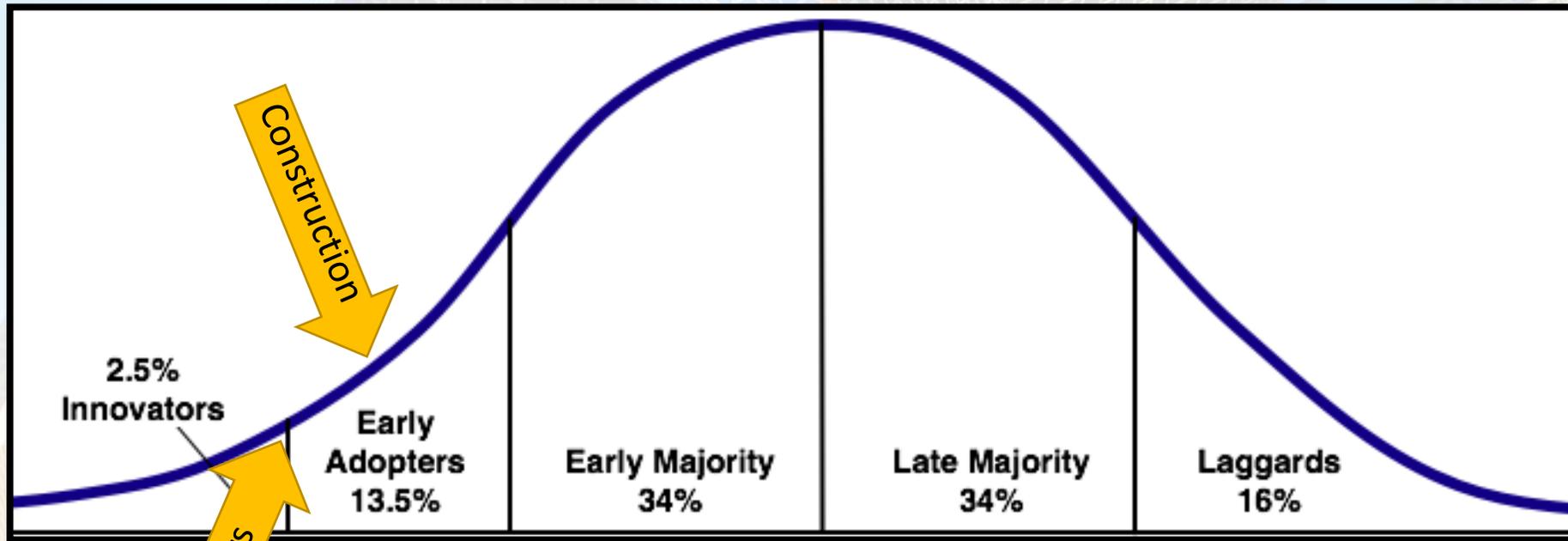
Trim the Fat! (waste)

Lean Success in Other Industries

- Manufacturing
- Health Care
- Finance
- Software Development
- Education
- Construction



Lean Construction & Design Continuum



Source: Rogers Diffusion of Innovation

3-Legged Construction Stool



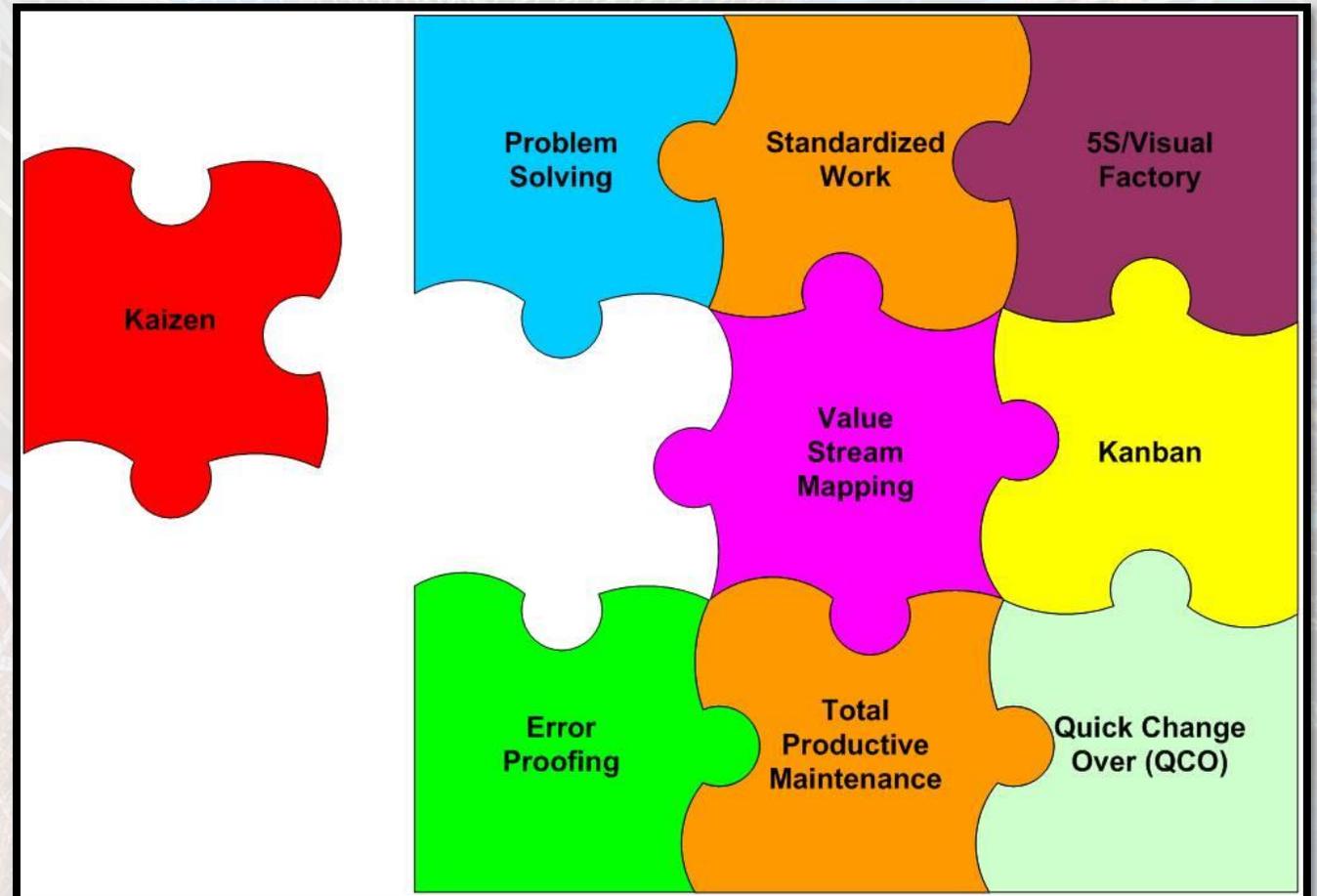
Lean Tools vs. Lean Thinking

All lean tools and concepts are applicable to any sector of the industry.

CAUTION

But, tools used in isolation will not produce the intended results.

Many lean tools to choose from



TOOL #1: Value Stream Mapping

Residential construction example (2008)

Centex[®]

\$3400 per home budgeted waste

Current Industry Perspective was...

- “I’ll just pass it on to the buyer/owner”
- “It’s just part of doing business”



Let's do the Math

\$3400 Budgeted Waste

x1300 Homes/yr

\$4.42M Waste/yr

That's \$4.42M in lost profits

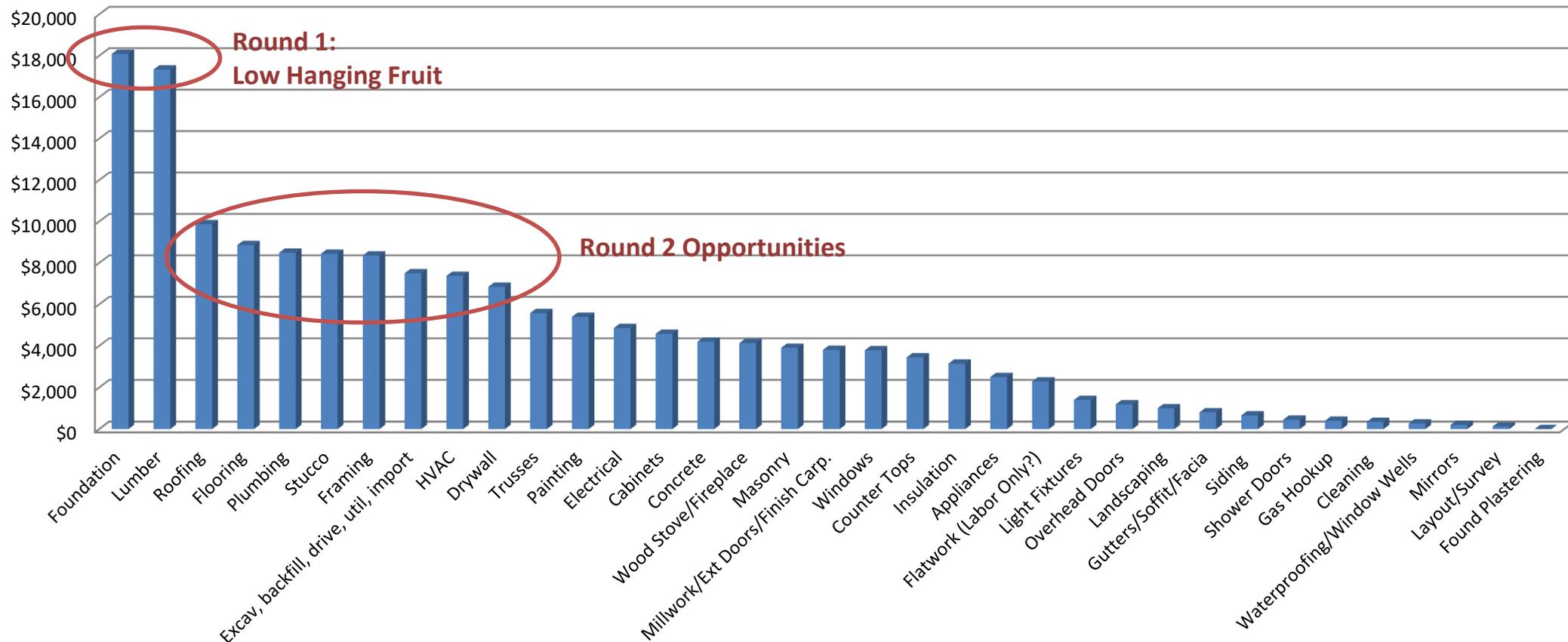
or

An opportunity to reduce costs
and increase market share



Prioritized Trades by Cost

Brick & Mortar Costs by Trade

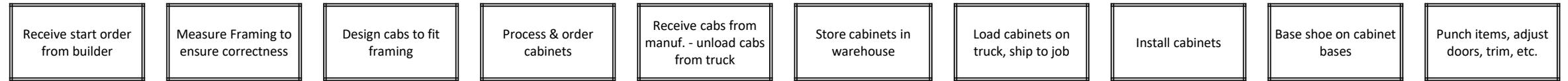


Cabinet Value Stream Mapping

- Attendees:
 - Operations Manager
 - Project Manager
 - Trade Contractor Owner
 - Trade Contractor Financial Officer
 - Trade Field Manager

VSM Procedures:

- Outline the process
- Quantify each task with
 1. Manpower
 2. Costs
- Identify waste
- Eliminate waste



Cabinet Value Stream Mapping

- Attendees:
 - Operations Manager
 - Project Manager
 - Trade Contractor Owner
 - Trade Contractor Financial Officer
 - Trade Field Manager

VSM Procedures:

- Outline the process
- Quantify each task with
 1. Manpower
 2. Costs
- Identify waste
- Eliminate waste

| | | | | | | | | | |
|----------------------------------|---|----------------------------------|------------------------------------|---|-----------------------------|--|--------------------------------------|-------------------------------|---------------------------------------|
| Receive start order from builder | Measure Framing to ensure correctness | Design cabs to fit framing | Process & order cabinets | Receive cabs from manuf. - unload cabs from truck | Store cabinets in warehouse | Load cabinets on truck, ship to job | Install cabinets | Base shoe on cabinet bases | Punch items, adjust doors, trim, etc. |
| | 1.5 hrs include. travel 1 staff employee \$82 | 1 hr 1 staff employee \$36 | .5 hrs 1 staff employee \$24 | 15 min. 2 warehouse employees \$30 | 13 work days | 15 min. 2 warehouse employees \$30 | 6-10 hrs 1 carpenter \$320-460 | 1 hr 1 QC employee \$36 | 1.5 hrs 1 QC employee \$18 |

Cabinet Value Stream Mapping

- Attendees:
 - Operations Manager
 - Project Manager
 - Trade Contractor Owner
 - Trade Contractor Financial Officer
 - Trade Field Manager

VSM Procedures:

- Outline the process
- Quantify each task with
 1. Manpower
 2. Costs
- Identify waste
- Eliminate waste

| | | | | | | | | | |
|----------------------------------|---|----------------------------------|------------------------------------|---|-----------------------------|--|--------------------------------------|-------------------------------|---------------------------------------|
| Receive start order from builder | Measure Framing to ensure correctness | Design cabs to fit framing | Process & order cabinets | Receive cabs from manuf. - unload cabs from truck | Store cabinets in warehouse | Load cabinets on truck, ship to job | Install cabinets | Base shoe on cabinet bases | Punch items, adjust doors, trim, etc. |
| | 1.5 hrs include. travel 1 staff employee \$82 | 1 hr 1 staff employee \$36 | .5 hrs 1 staff employee \$24 | 15 min. 2 warehouse employees \$30 | 13 work days | 15 min. 2 warehouse employees \$30 | 6-10 hrs 1 carpenter \$320-460 | 1 hr 1 QC employee \$36 | 1.5 hrs 1 QC employee \$18 |

Cabinet Value Stream Mapping

- Attendees:
 - Operations Manager
 - Project Manager
 - Trade Contractor Owner
 - Trade Contractor Financial Officer
 - Trade Field Manager

VSM Procedures:

- Outline the process
- Quantify each task with
 1. Manpower
 2. Costs
- Identify waste
- Eliminate waste

| | | | | | | | | | |
|----------------------------------|---|----------------------------------|------------------------------------|---|-----------------------------|--|--------------------------------------|-------------------------------|---------------------------------------|
| Receive start order from builder | Measure Framing to ensure correctness | Design cabs to fit framing | Process & order cabinets | Receive cabs from manuf. - unload cabs from truck | Store cabinets in warehouse | Load cabinets on truck, ship to job | Install cabinets | Base shoe on cabinet bases | Punch items, adjust doors, trim, etc. |
| | 1.5 hrs include. travel 1 staff employee \$82 | 1 hr 1 staff employee \$36 | .5 hrs 1 staff employee \$24 | 15 min. 2 warehouse employees \$30 | 13 work days | 15 min. 2 warehouse employees \$30 | 6-10 hrs 1 carpenter \$320-460 | 1 hr 1 QC employee \$36 | 1.5 hrs 1 QC employee \$18 |

Cabinet Value Stream Mapping

- Attendees:
 - Operations Manager
 - Project Manager
 - Trade Contractor Owner
 - Trade Contractor Financial Officer
 - Trade Field Manager

VSM Procedures:

- Outline the process
- Quantify each task with
 1. Manpower
 2. Costs
- Identify waste
- Eliminate waste

| | | | | | | | | | |
|----------------------------------|---|----------------------------------|------------------------------------|---|-----------------------------|--|--------------------------------------|-------------------------------|---------------------------------------|
| Receive start order from builder | Measure Framing to ensure correctness | Design cabs to fit framing | Process & order cabinets | Receive cabs from manuf. - unload cabs from truck | Store cabinets in warehouse | Load cabinets on truck, ship to job | Install cabinets | Base shoe on cabinet bases | Punch items, adjust doors, trim, etc. |
| | 1.5 hrs include. travel 1 staff employee \$82 | 1 hr 1 staff employee \$36 | .5 hrs 1 staff employee \$24 | 15 min. 2 warehouse employees \$30 | 13 work days | 15 min. 2 warehouse employees \$30 | 6-10 hrs 1 carpenter \$320-460 | 1 hr 1 QC employee \$36 | 1.5 hrs 1 QC employee \$18 |

Cabinet Value Stream Mapping

- Attendees:
 - Operations Manager
 - Project Manager
 - Trade Contractor Owner
 - Trade Contractor Financial Officer
 - Trade Field Manager

VSM Procedures:

- Outline the process
- Quantify each task with
 - Manpower
 - Costs
- Identify waste
- Eliminate waste

| | | | | | | | | | |
|----------------------------------|---|----------------------------------|------------------------------------|---|-----------------------------|--|--------------------------------------|-------------------------------|---------------------------------------|
| Receive start order from builder | Measure Framing to ensure correctness | Design cabs to fit framing | Process & order cabinets | Receive cabs from manuf. - unload cabs from truck | Store cabinets in warehouse | Load cabinets on truck, ship to job | Install cabinets | Base shoe on cabinet bases | Punch items, adjust doors, trim, etc. |
| | 1.5 hrs include. travel 1 staff employee \$82 | 1 hr 1 staff employee \$36 | .5 hrs 1 staff employee \$24 | 15 min. 2 warehouse employees \$30 | 13 work days | 15 min. 2 warehouse employees \$30 | 6-10 hrs 1 carpenter \$320-460 | 1 hr 1 QC employee \$36 | 1.5 hrs 1 QC employee \$18 |

Cabinet Value Stream Mapping

- Attendees:
 - Operations Manager
 - Project Manager
 - Trade Contractor Owner
 - Trade Contractor Financial Officer
 - Trade Field Manager

VSM Procedures:

- Outline the process
- Quantify each task with
 - Manpower
 - Costs
- Identify waste
- Eliminate waste

| | | | | | | | | | |
|----------------------------------|---|----------------------------------|------------------------------------|---|-----------------------------|--|--------------------------------------|-------------------------------|---------------------------------------|
| Receive start order from builder | Measure Framing to ensure correctness | Design cabs to fit framing | Process & order cabinets | Receive cabs from manuf. - unload cabs from truck | Store cabinets in warehouse | Load cabinets on truck, ship to job | Install cabinets | Base shoe on cabinet bases | Punch items, adjust doors, trim, etc. |
| | 1.5 hrs include. travel 1 staff employee \$82 | 1 hr 1 staff employee \$36 | .5 hrs 1 staff employee \$24 | 15 min. 2 warehouse employees \$30 | 13 work days | 15 min. 2 warehouse employees \$30 | 6-10 hrs 1 carpenter \$320-460 | 1 hr 1 QC employee \$36 | 1.5 hrs 1 QC employee \$18 |

Cabinet Value Stream Mapping

- Attendees:

- Operations Manager
- Project Manager
- Trade Contractor Owner
- Trade Contractor Financial Officer
- Trade Field Manager

VSM Procedures:

- Outline the process
- Quantify each task with
 1. Manpower
 2. Costs
- Identify waste
- Eliminate waste

| | | | | | | | | | |
|----------------------------------|---|----------------------------------|------------------------------------|---|-----------------------------|--|--------------------------------------|-------------------------------|---------------------------------------|
| Receive start order from builder | Measure Framing to ensure correctness | Design cabs to fit framing | Process & order cabinets | Receive cabs from manuf. - unload cabs from truck | Store cabinets in warehouse | Load cabinets on truck, ship to job | Install cabinets | Base shoe on cabinet bases | Punch items, adjust doors, trim, etc. |
| | 1.5 hrs include. travel 1 staff employee \$82 | 1 hr 1 staff employee \$36 | .5 hrs 1 staff employee \$24 | 15 min. 2 warehouse employees \$30 | 13 work days | 15 min. 2 warehouse employees \$30 | 6-10 hrs 1 carpenter \$320-460 | 1 hr 1 QC employee \$36 | 1.5 hrs 1 QC employee \$18 |

Cabinet Value Stream Mapping

- Attendees:
 - Operations Manager
 - Project Manager
 - Trade Contractor Owner
 - Trade Contractor Financial Officer
 - Trade Field Manager

VSM Procedures:

- Outline the process
- Quantify each task with
 1. Manpower
 2. Costs
- Identify waste
- Eliminate waste

| | | | | | | | | | |
|----------------------------------|---|----------------------------------|------------------------------------|---|-----------------------------|--|--------------------------------------|-------------------------------|---------------------------------------|
| Receive start order from builder | Measure Framing to ensure correctness | Design cabs to fit framing | Process & order cabinets | Receive cabs from manuf. - unload cabs from truck | Store cabinets in warehouse | Load cabinets on truck, ship to job | Install cabinets | Base shoe on cabinet bases | Punch items, adjust doors, trim, etc. |
| | 1.5 hrs include. travel 1 staff employee \$82 | 1 hr 1 staff employee \$36 | .5 hrs 1 staff employee \$24 | 15 min. 2 warehouse employees \$30 | 13 work days | 15 min. 2 warehouse employees \$30 | 6-10 hrs 1 carpenter \$320-460 | 1 hr 1 QC employee \$36 | 1.5 hrs 1 QC employee \$18 |

Cabinet Value Stream Mapping

- Attendees:

- Operations Manager
- Project Manager
- Trade Contractor Owner
- Trade Contractor Financial Officer
- Trade Field Manager

VSM Procedures:

- Outline the process
- Quantify each task with
 1. Manpower
 2. Costs
- Identify waste
- Eliminate waste

| | | | | | | | | | |
|----------------------------------|---|----------------------------------|------------------------------------|---|-----------------------------|--|--------------------------------------|-------------------------------|---------------------------------------|
| Receive start order from builder | Measure Framing to ensure correctness | Design cabs to fit framing | Process & order cabinets | Receive cabs from manuf. - unload cabs from truck | Store cabinets in warehouse | Load cabinets on truck, ship to job | Install cabinets | Base shoe on cabinet bases | Punch items, adjust doors, trim, etc. |
| | 1.5 hrs include. travel 1 staff employee \$82 | 1 hr 1 staff employee \$36 | .5 hrs 1 staff employee \$24 | 15 min. 2 warehouse employees \$30 | 13 work days | 15 min. 2 warehouse employees \$30 | 6-10 hrs 1 carpenter \$320-460 | 1 hr 1 QC employee \$36 | 1.5 hrs 1 QC employee \$18 |

Cabinet Value Stream Mapping

- Attendees:
 - Operations Manager
 - Project Manager
 - Trade Contractor Owner
 - Trade Contractor Financial Officer
 - Trade Field Manager

VSM Procedures:

- Outline the process
- Quantify each task with
 1. Manpower
 2. Costs
- Identify waste
- Eliminate waste

| | | | | | | | | | |
|----------------------------------|---|----------------------------------|------------------------------------|---|-----------------------------|--|--------------------------------------|-------------------------------|---------------------------------------|
| Receive start order from builder | Measure Framing to ensure correctness | Design cabs to fit framing | Process & order cabinets | Receive cabs from manuf. - unload cabs from truck | Store cabinets in warehouse | Load cabinets on truck, ship to job | Install cabinets | Base shoe on cabinet bases | Punch items, adjust doors, trim, etc. |
| | 1.5 hrs include. travel 1 staff employee \$82 | 1 hr 1 staff employee \$36 | .5 hrs 1 staff employee \$24 | 15 min. 2 warehouse employees \$30 | 13 work days | 15 min. 2 warehouse employees \$30 | 6-10 hrs 1 carpenter \$320-460 | 1 hr 1 QC employee \$36 | 1.5 hrs 1 QC employee \$18 |

What exactly is Value?

Value is **always** determined from the customer's perspective

Value is created when trades are physically constructing the product

Examples of Adding Value:

- Pouring concrete
- Erecting steel
- Installing roof

Essential Non-Value Added tasks:

- Production meeting
- Ordering materials
- Processing RFI's



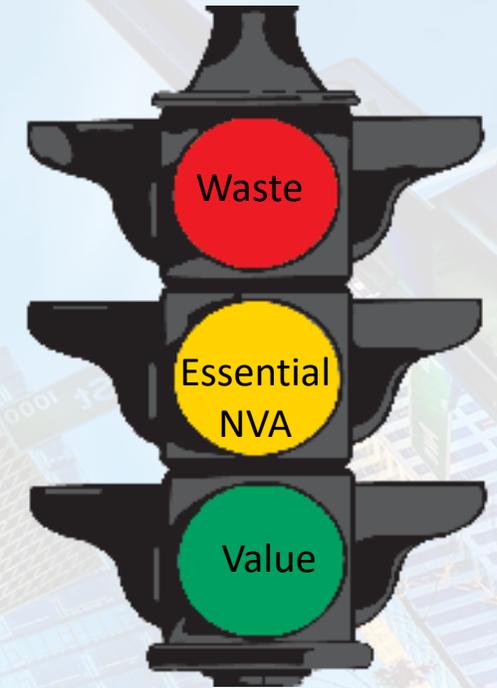
What exactly is Value?

TRANSFORMATION of MATERIALS!



Identify Waste & Value

- The only real Value to the customer/buyer is installation because they receive the product
- Identify Waste, Value & Essential Non-Value Added Activities



| | | | | | | | | | |
|---|---|----------------------------------|------------------------------------|---|---|---|--------------------------------------|--|---------------------------------------|
| Receive start order from builder | Measure Framing to ensure correctness | Design cabs to fit framing | Process & order cabinets | Receive cabs from manuf, unload cabs from truck | Store cabinets in warehouse | Load cabinets on truck, ship to job | Install cabinets | Base shoe on cabinet bases | Punch items, adjust doors, trim, etc. |
| Order required 3 weeks prior to cabinet install task on schedule. | Production homes - framing shouldn't vary from plan. Eliminate | Eliminate | | | Could manufacturer drop-ship cabinets to each home? | Installers to deliver cabinets the day of install. Eliminate | | Installer to complete base shoe and all adjustments the day of install. Checklist verification by FM for FPY. Eliminate | Eliminate |
| | 1.5 hrs include. travel 1 staff employee \$82 | 1 hr 1 staff employee \$36 | .5 hrs 1 staff employee \$24 | 15 min. 2 warehouse employees \$30 | 13 work days | 15 min. 2 warehouse employees \$30 | 6-10 hrs 1 carpenter \$320-460 | 1 hr 1 QC employee \$36 | 1.5 hrs 1 QC employee \$18 |

Eliminating Waste

- Waste **CANNOT** be eliminated just because it's waste.
- Create a waste elimination plan
 - Start with the largest Non-Value Added (waste) step
 - Identify impediments to eliminating NVA steps
 - Understand who will be affected
 - Analyze how the organization contributes to NVA steps
 - Analyze how other organizations contribute
 - Determine who owns the problem
 - **Eliminate the waste**



©2014 Creative Safety Supply

The most difficult \$118 ever saved

Measure Framing to ensure correctness

Design cabs to fit framing

Production homes - framing shouldn't vary from plan. **Eliminate**

Eliminate

1.5 hrs include. travel

1 staff employee

\$82

1 hr

1 staff employee

\$36

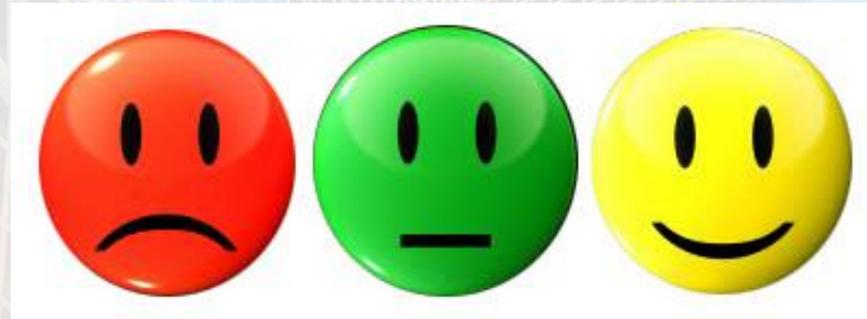
Reasons for waste

- Cabinet contractor has been burned in the past due to:
 - Incorrect plans
 - Incorrect framing installation
 - Incorrect cabinet layout
 - Partially documented plan changes

Imagine the problems that would occur if these steps were eliminated with no thought in the matter

Back to the VSM Event

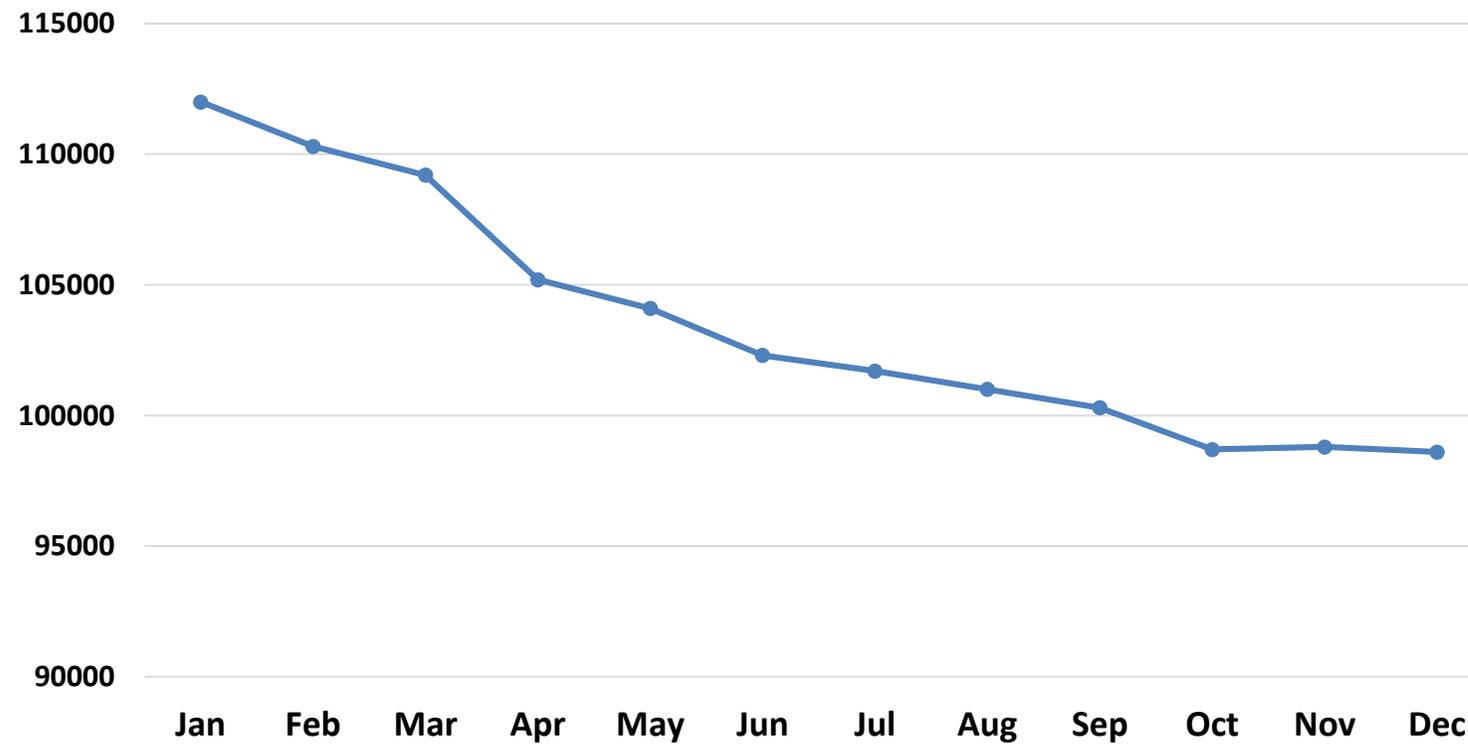
- How is the trade contractor feeling at this point in the meeting?



- Rules to live by...
 - Commit to change before you require it of others
 - Don't blame the person, blame the current process
 - Build the right team (positive leadership)
- It took us 6 months to eliminate those two “waste steps”

VSM/Lean Results

Direct Costs Δ



- Improved Quality
- Decreased Schedule Durations
- Increased Schedule Reliability
- Improved Morale
- Increased Profits/Savings

Savings Captured after VSM

\$112,100 starting direct costs

-\$98,600 after VSM

\$13,500 savings (13.7%)

\$13,500 savings

x 1300 homes/yr

\$17.6M savings/yr



Is that REALLY possible?

- We changed our company culture to a Win/Win partnership approach
- We didn't demand anything from the trades that we weren't willing to do ourselves
- We became lean construction teachers/trainers
- We replaced a few trade contractors who refused to "buy in"
- We used LOTS of other lean strategies to improve customer value and eliminate waste
- It was a LOT of work, but a LOT of fun!

How did we increase Value?

REMEMBER: Value is always determined from the customer's perspective

- As you eliminate a Non-Value Added task the only tasks left have more value to the customer.
- **Waste costs a lot!**

What does the customer want?

- Quality product
- On-time delivery
- On budget



Added Value (Scheduling)

BEFORE LEAN

Home started 3-4 months after customer signed contract



AFTER LEAN

Home started less than one month after signed contract

134 day schedule



81 day schedule

Customer moves in FIVE months earlier



Added Value (Quality)

BEFORE



BEFORE



AFTER



Added Value (Schedule, Quality, Costs)



Schedule:

- Owners/buyers were able to move in 4-5 months earlier

Quality:

- JD Power customer satisfaction quality scores increased

Costs:

- Sales prices decreased over time



You CAN have all 3

What we have learned so far...

- **Waste = \$**
- When you can reduce waste, you also increase profits or save money
- When quality improves, you increase customer value
- When you complete a project in less time, you save money
- CM, FM, Design, Trade contractors can utilize lean processes

Lean =



Lean =  Value,  Waste

Lean in Commercial Design & Construction

- More stakeholders
- More products
- More trades
- More assemblies
- More complexity



Planning & Scheduling with Lean

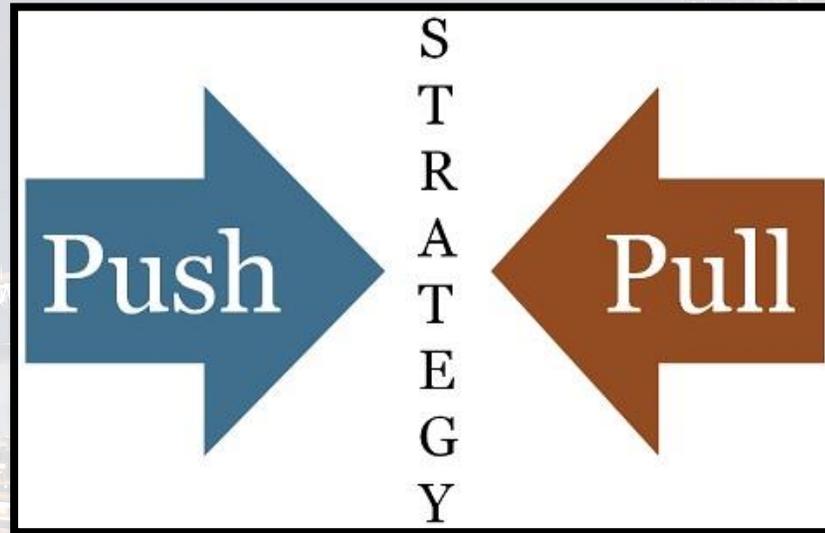




54%

The average % of completed tasks in a week

Traditional Management vs. Lean Management



- **PUSH:** Creates project schedules based on predetermined dates & durations
 - Without input from the specialists (subcontractor)
- **PUSH:** Trades focus on improving performance of their individual operations
 - Often at the expense of others
- **PUSH:** Management assumes that when workers are busy, they are productive

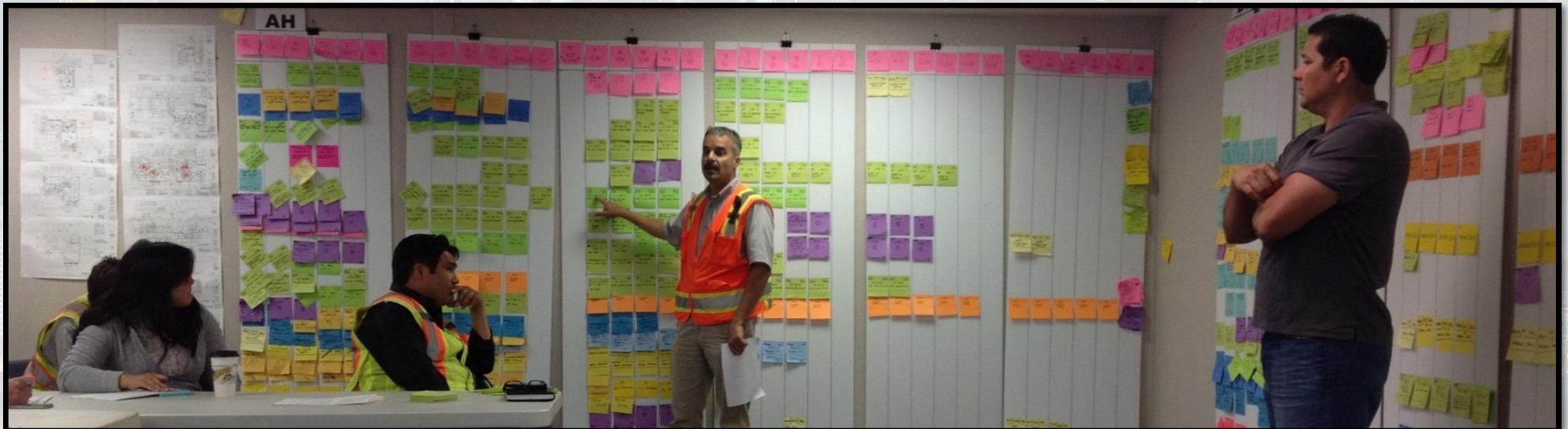
Push vs. Pull Planning

- All plans are forecasts and all forecasts are **wrong**. The longer the forecast, the more **wrong** it is! The more detailed the forecast, the more **wrong** it is!
Ballard & Howell
- Traditional scheduling is based on **predetermined** completion dates (predictions) regardless of whether workers are ready to start work.



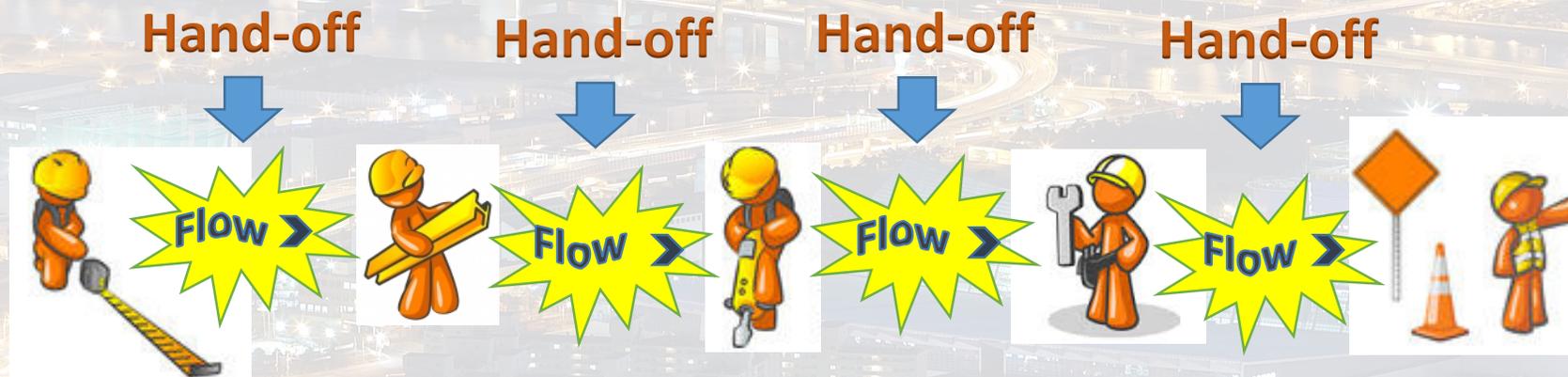
TOOL #2: Last Planner System (LPS)

- Most common starting point for construction & design firms
- Commonly called **PULL**-planning
- Facilitated by the Super or PM but foreman are the last planners

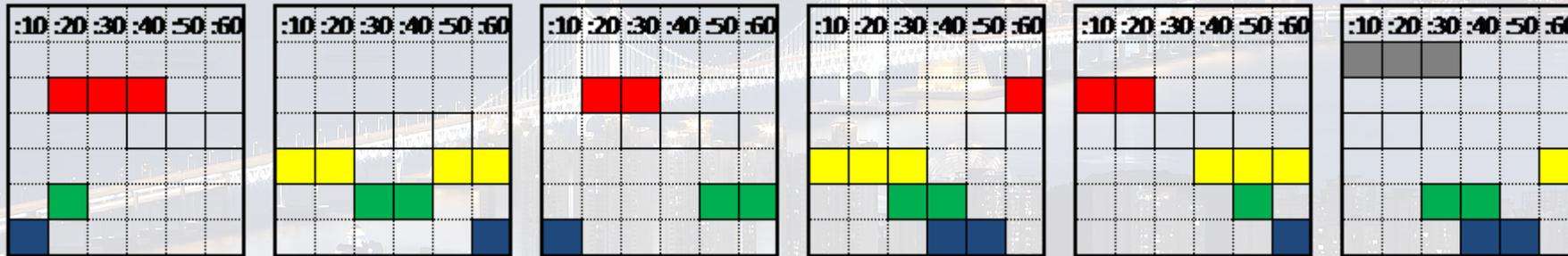


Push Scheduling vs. Pull Planning

- Traditional managers seek to manage by **PUSH & after-the-fact variance detection** (reactionary)
- Lean seeks to manage by **PULL & in-process learning & adjusting** (proactive)



Pull Planning



- Backwards (pull) scheduling
- Impeccable coordination
- Reliable commitments
- Formalized learning

| | |
|--|---|
| COMPANY | |
| SCOPE/DISCIPLINE | C+O |
| WHAT I NEED FROM OTHERS | |
| 1. | CASEWORK |
| 2. | |
| 3. | |
| WHAT I WILL DELIVER TO THE PROJECT | |
| DELIVERABLE | FINISH COAT PAINT S-2 MAIN CORRIDOR |
| CONCENTRATED EFFORT TIME (HOURS/DAYS) | → 4 |
| DELIVERY DATE CIRCLE ONE: | 2/23 |
| OFB NOON COB EOD | (open for business) (close of business) (end of day/midnight) |
| COURTESY OF DPR CONSTRUCTION, INC. © 2007 DPR Construction, Inc. www.dprinc.com | |

LPS Overview

View from
outer space

Cockpit's view

Bird's eye view

Ground-level

Hindsight

**STRATEGIC
SHOULD**

MASTER SCHEDULING

PROJECT PLANNING

Managers ...

Set milestones
Identify long leads

**PRODUCTION
SHOULD**

PHASE SCHEDULING

Last Planners ...

Specify hand-offs

CAN

LOOKAHEAD PLANNING

Builders plan in detail
Make ready work

WILL

**WEEKLY WORK
PLANNING**

Crew assignments
Reliable promises

DID

LEARNING

Measure PPC
Learn from plan failures

PRODUCTION PLANNING

Master Schedule – What SHOULD Be Done

View from
outer space

**STRATEGIC
SHOULD**

MASTER SCHEDULING

Managers ...

Set milestones
Identify long leads

PROJECT PLANNING

**PRODUCTION
SHOULD**

PHASE SCHEDULING

Last Planners ...

Specify hand-offs

CAN

LOOKAHEAD PLANNING

Builders plan in detail
Make ready work

WILL

**WEEKLY WORK
PLANNING**

Crew assignments
Reliable promises

DID

LEARNING

Measure PPC
Learn from plan failures

PRODUCTION PLANNING

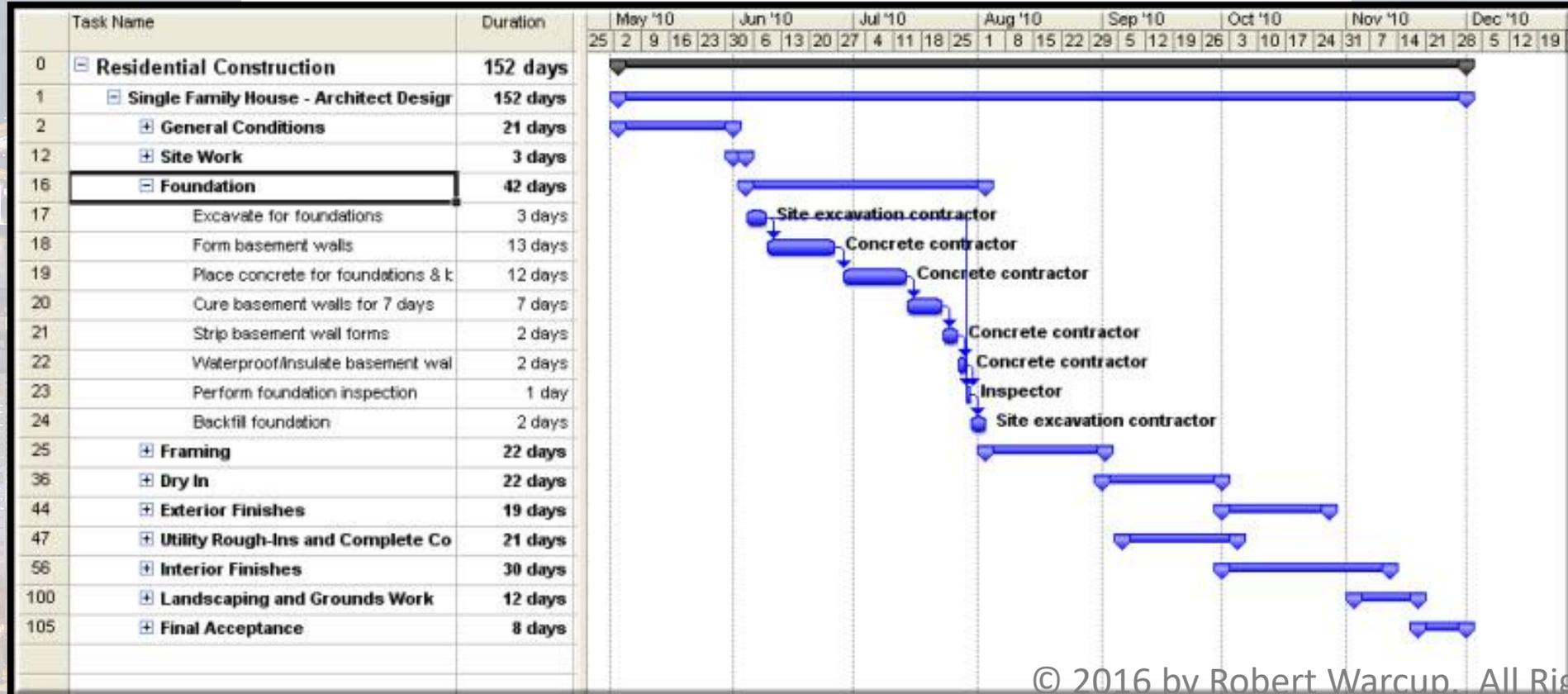
Master Schedule – What SHOULD Be Done

**STRATEGIC
SHOULD**

MASTER SCHEDULING

PROJECT PLANNING

Managers ...
Set milestones
Identify long leads



Phase Scheduling – What SHOULD Be Done

Cockpit's view

STRATEGIC
SHOULD

MASTER SCHEDULING

PROJECT PLANNING

Managers ...

Set milestones
Identify long leads

PRODUCTION
SHOULD

PHASE SCHEDULING

Last Planners ...

Specify hand-offs

CAN

LOOKAHEAD PLANNING

Builders plan in detail
Make ready work

WILL

WEEKLY WORK
PLANNING

Crew assignments
Reliable promises

DID

LEARNING

Measure PPC
Learn from plan failures

PRODUCTION PLANNING

Phase Scheduling – What SHOULD Be Done

STRATEGIC
SHOULD

MASTER SCHEDULING

PROJECT PLANNING

Managers ...

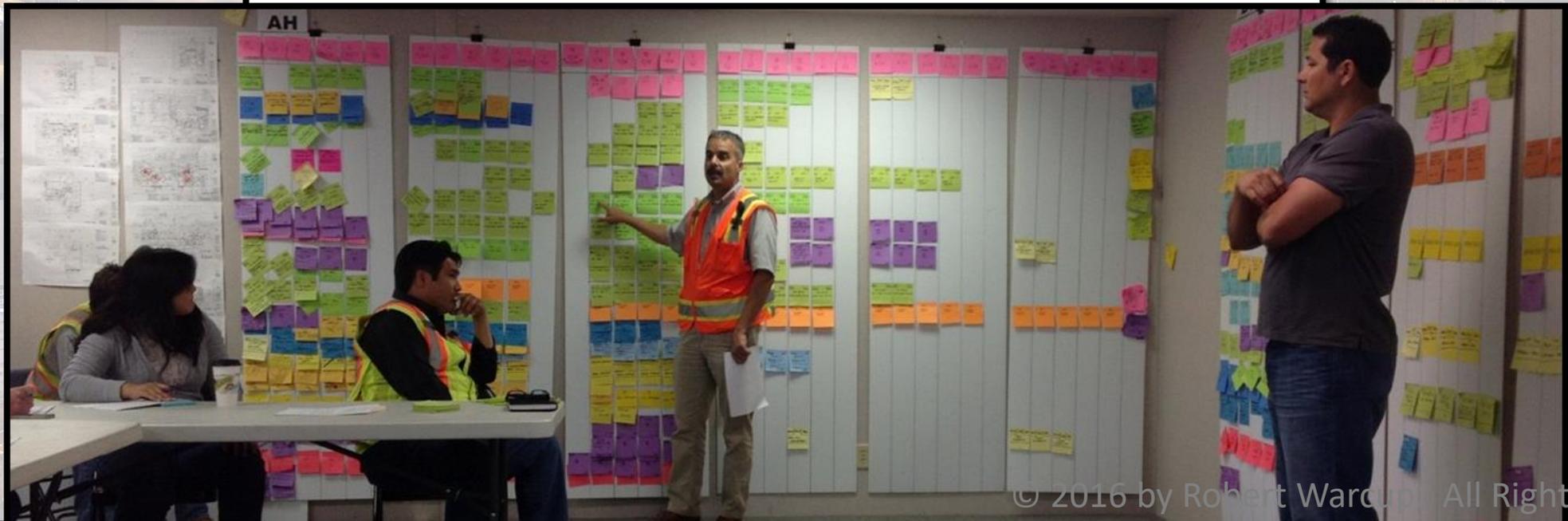
Set milestones
Identify long leads

PRODUCTION
SHOULD

PHASE SCHEDULING

Last Planners ...

Specify hand-offs



6-Week Look-ahead – What CAN Be Done

Bird's eye view

STRATEGIC
SHOULD

MASTER SCHEDULING

Managers ...
Set milestones
Identify long leads

PROJECT PLANNING

PRODUCTION
SHOULD

PHASE SCHEDULING

Last Planners ...
Specify hand-offs

CAN

LOOKAHEAD PLANNING

Builders plan in detail
Make ready work

WILL

WEEKLY WORK
PLANNING

Crew assignments
Reliable promises

DID

LEARNING

Measure PPC
Learn from plan failures

PRODUCTION PLANNING

6-Week Look-ahead – What CAN Be Done

- What's happening 6 weeks out that might effect production?
- What work needs to be made ready?

CAN

LOOKAHEAD PLANNING

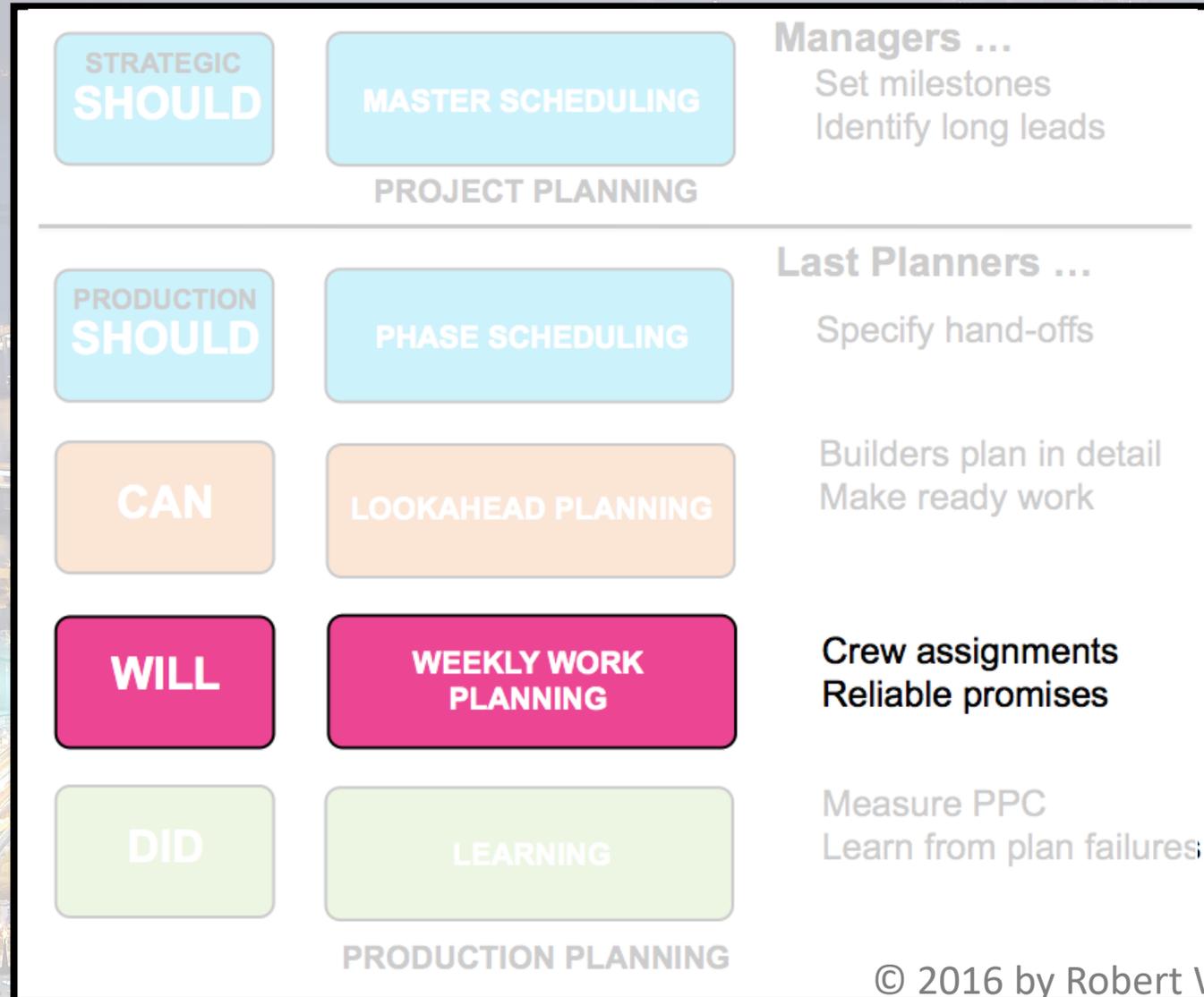
Builders plan in detail
Make ready work



VISUAL MANAGEMENT:

- Delivery board
- Inspection board
- Constraint board
- Work area board

Weekly Work Plan – What WILL Be Done



Ground-level

Formalized Learning- What WAS Done

STRATEGIC
SHOULD

MASTER SCHEDULING

Managers ...

Set milestones
Identify long leads

PROJECT PLANNING

PRODUCTION
SHOULD

PHASE SCHEDULING

Last Planners ...

Specify hand-offs

CAN

LOOKAHEAD PLANNING

Builders plan in detail
Make ready work

WILL

WEEKLY WORK
PLANNING

Crew assignments
Reliable promises

DID

LEARNING

Measure PPC
Learn from plan failures

PRODUCTION PLANNING

Hindsight

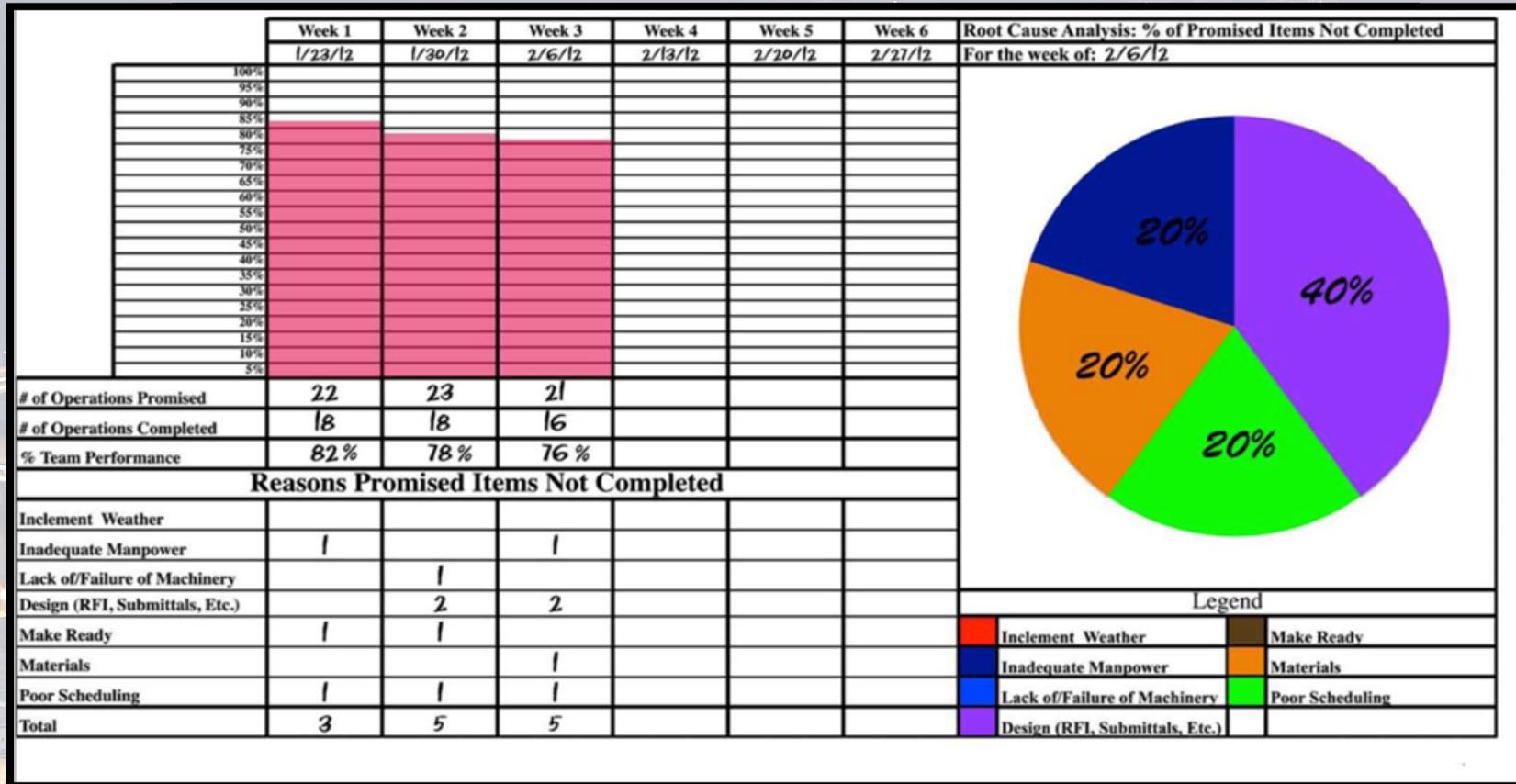
Formalized Learning – What WAS Done

- Percent Planned Complete (PPC)
- Root cause analysis
- Non-conformance tracking
- Make it **visual** for ALL to see
- Commitment is higher if manual



$$\text{PPC} = \frac{5 \text{ tasks completed in a week}}{8 \text{ tasks planned in a week}} = 62.5\%$$

Formalized Learning- What WAS Done



DID

LEARNING

PRODUCTION PLANNING

Measure PPC
Learn from plan failures

Weekly Production Meeting Sub Commitments

Weekly Work Plan & Planning



Contractor: CVE Week Ending: 5/30/2016 Week Ending: _____

| Work to Be Completed (constraints already removed - safety, material, RFIs, ...) | Floor/ Area | Make Ready Needs | Enter # Crew Members Req'd for Each Task | | | | | | 2-Week Look-Ahead Planning | | | | | |
|--|-------------|------------------|--|---|---|----|---|---|----------------------------|---|---|----|---|---|
| | | | M | T | W | Th | F | S | M | T | W | Th | F | S |
| Ground Site | | | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 | | | |
| Ground Inside | | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | | |
| Pulling 600V Wire | | | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | | | | |
| CT Conduit Install | | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | | | | | |
| Pole Light Bases | | | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | | |
| Security & Pole Light UG | | | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | | | |
| Bloom Wire Terms | | | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | | |
| Controls to Elevator Gear EPMS | | | 2 | 2 | 2 | 2 | 2 | 2 | | | | | | |
| Conduit and Wiring for BMS | | | 7 | 7 | 7 | 7 | 7 | 7 | | | | | | |
| Ladder Rack | | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | | | | | |
| CT Pipe and Wire BMS | | | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | | | | |

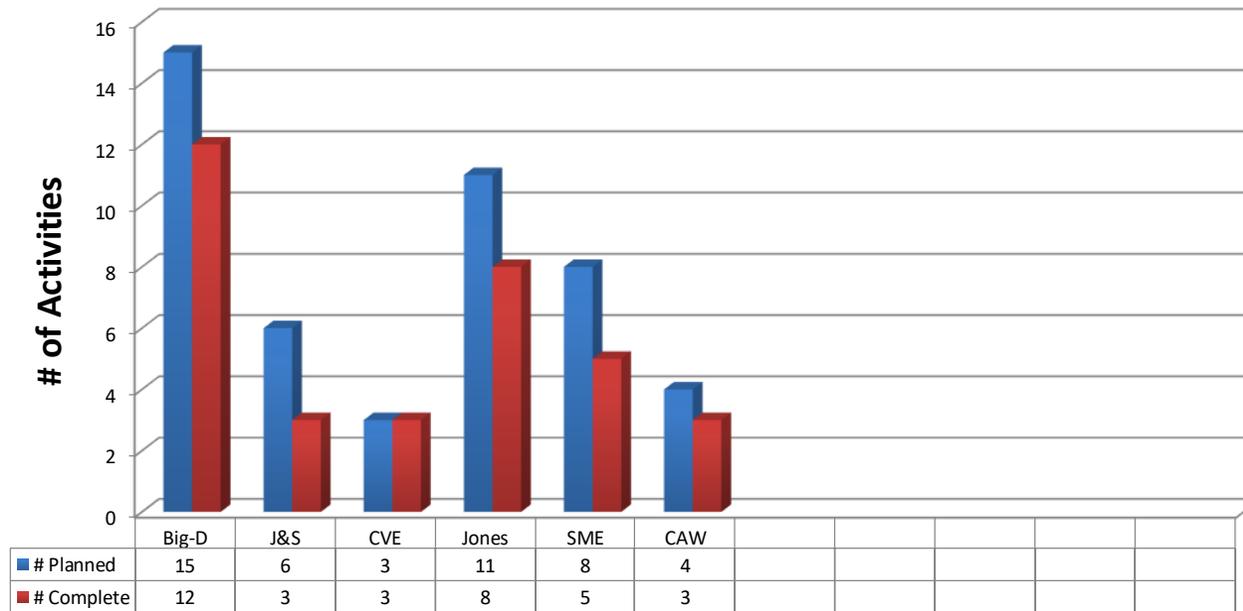
Weekly Production Meeting Sub Commitments

Appropriate Tasks:

- **Defined**: Specific wording, containing the right information
- **Defined**: Must be coordinated with other trades
- **Size**: Sized to smaller increments so all can judge whether they were completed by week's end
- **Soundness**: Workable, ready to execute
- **Sequenced**: Prioritized and sequenced to milestones
 - Example: Pour footings vs. pour footing, north wall, bldg 3. Duration: one day, start: 2.11.15, finish: 2.11.15.

Subcontractor PPC Tracking

Sub-Specific PPC Tracking



Week Ending 05-30-14

Weekly PPC

Week Ending: 5/30/2016

| Company | # Planned | # Complete | Weekly PPC |
|---------------|-----------|------------|------------|
| 1 Big-D | 15 | 12 | 80% |
| 2 J&S | 6 | 3 | 50% |
| 3 CVE | 3 | 3 | 100% |
| 4 Jones | 11 | 8 | 73% |
| 5 SME | 8 | 5 | 63% |
| 6 CAW | 4 | 3 | 75% |
| 7 | | | |
| 8 | | | |
| 9 | | | |
| 10 | | | |
| 11 | | | |
| TOTALS | 47 | 34 | 72% |

Enter data in white cells.

Enter weekly PPC for each Sub to the right for Sub-specific data

PPC Guidelines

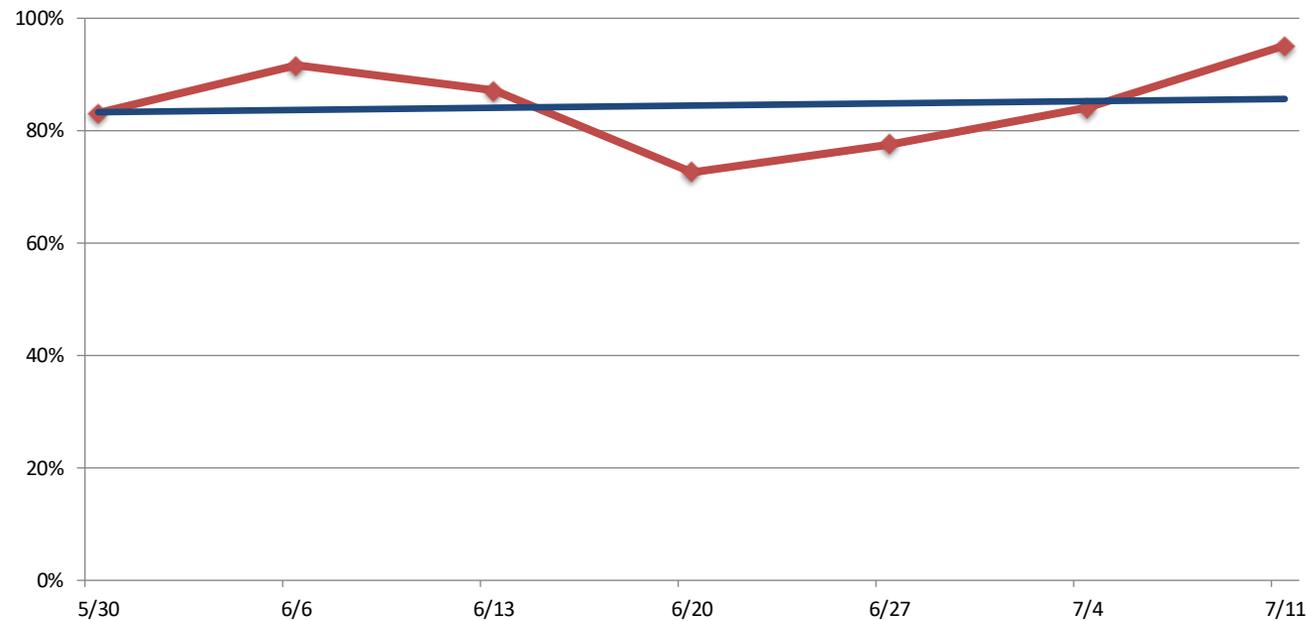
On-Time Task Completion 100% (not 99%)

No Early Completion

Dependent Customer or Super verifies completion

Project-Level PPC Tracking

Project-Level PPC History



Sub-Specific PPC History

| Company | Project Avg. |
|---------|--------------|
| 1 Big-D | 77% |
| 2 J&S | 94% |
| 3 CVE | 84% |
| 4 Jones | 69% |
| 5 SME | 78% |
| 6 CAW | 84% |
| 7 | |
| 8 | |
| 9 | |
| 10 | |
| 11 | |

Best Practice: Lean Boards and the Daily Huddle



- Attended by the Super & trade foremen
- Held in the work area
- First thing in the morning
- Lean training

Best Practice: Lean Boards and the Daily Huddle

- Discuss prior day's activities
 - Daily PPC
 - Non-conformances (learning)



- Discuss current day's activities
 - Confirm commitments
 - Work area coordination
 - Safety, etc.

More Lean Boards and the Daily Huddle

- Delivery Board
- Constraint/Resolution Board
- Issue/Action Board
- Safety Board
- Percent Planned Complete (PPC) Board
- Workspace Board
- Inspection Board



LPS Results

- **Projects without LPS = 54% PPC**
- **Projects using LPS = 85% PPC**
- Delivers bad news early & eliminates fire-fighting
- Improves project collaboration, morale, safety & helps increase value

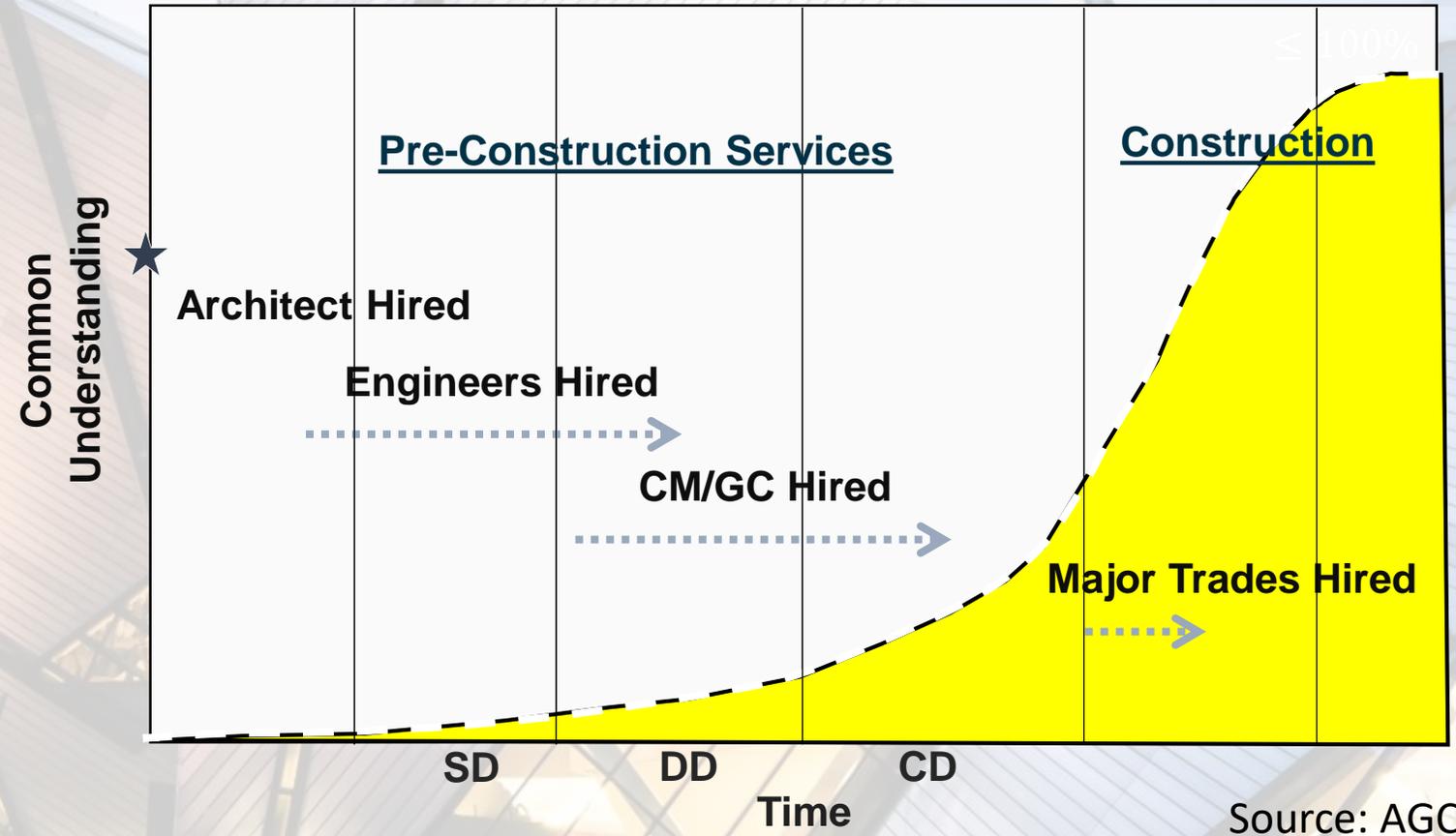


Lean Design Strategies



© 2016 by Robert Warcup. All Rights Reserved.

Traditional Project Delivery



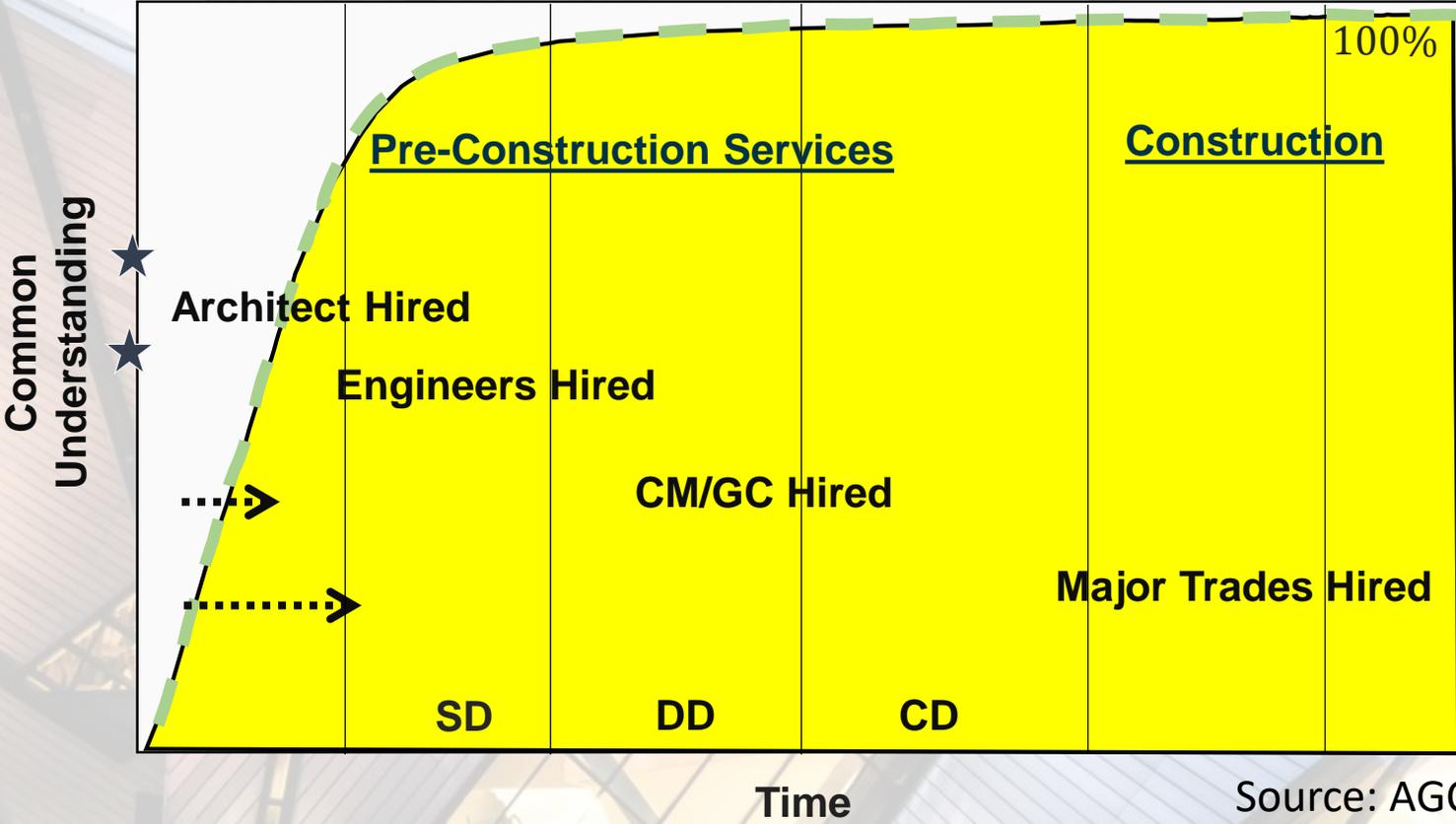
Source: AGC LCEP

Common Design Problems

- Sub-consultants have difficulties defining or measuring values
- Integration difficulties
- Challenge of designing to set budgets
- Missed opportunities for adding and capitalizing on value
- Typical fee structures do not have incentives for adding value

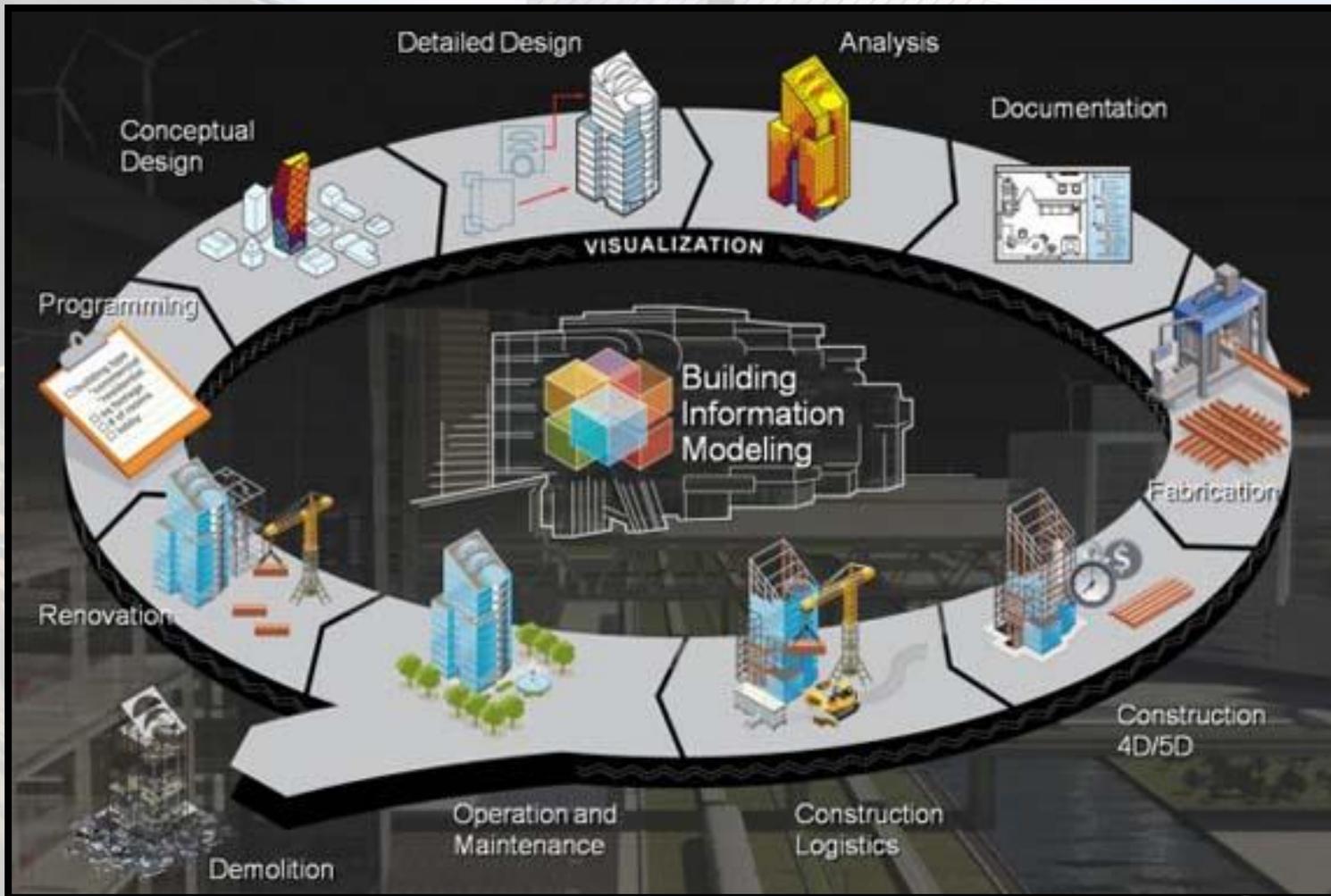


Lean Project Delivery



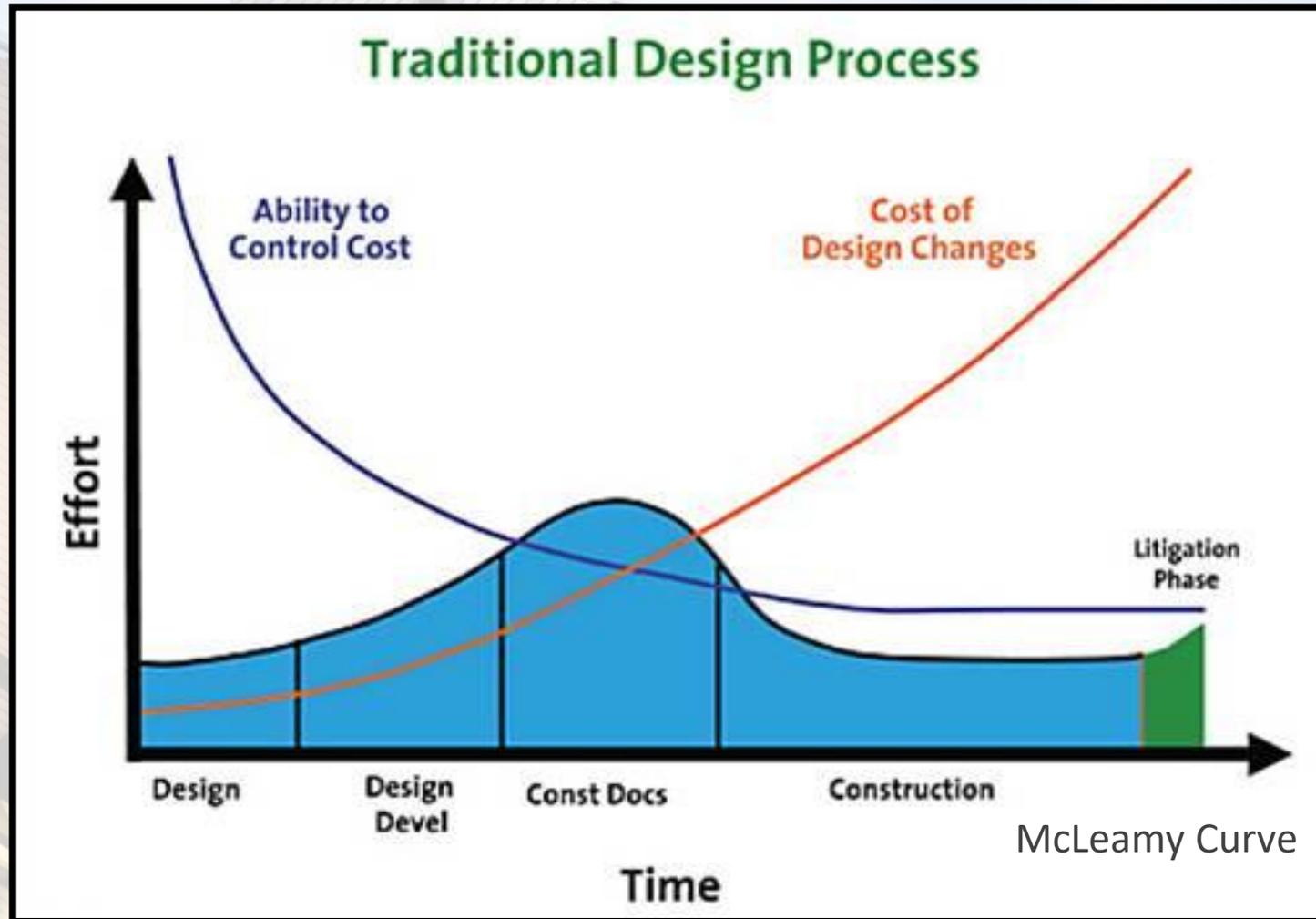
Source: AGC LCEP

Does BIM Eliminate Waste?



- Clash detect.
- Pre-fab
- 7D model
 - X, Y & Z
 - 4D: Time
 - 5D: Cost
 - 6D: Sustain
 - 7D: FM & Perform.

Waste in Design

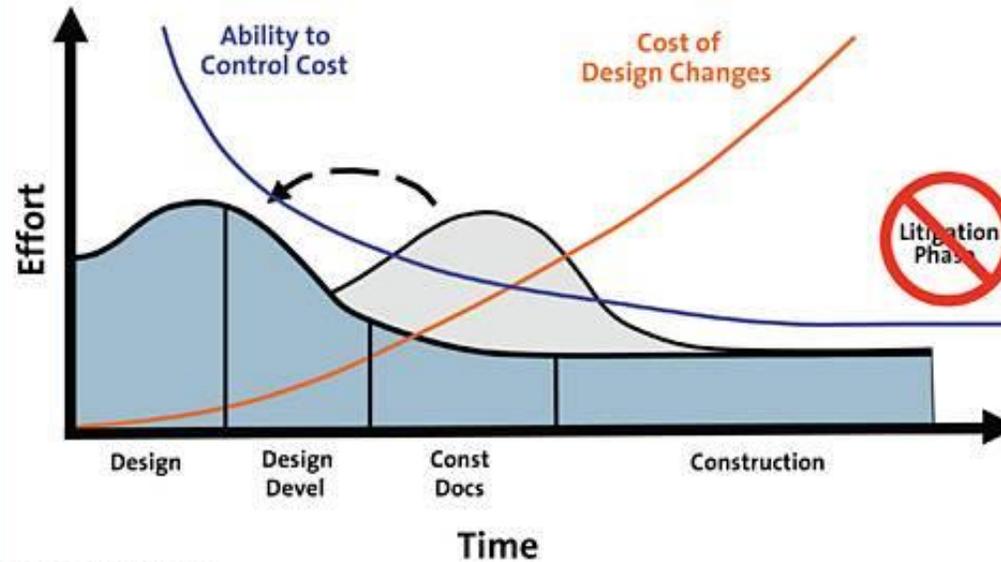


Integrated Project Delivery (IPD)

Integrated Project Delivery: The Future of Construction

Integrated Project Process

- Documenting as the model is built
- Involving Construction/Suppliers
- Eliminating clashes



Graphics courtesy of HOK

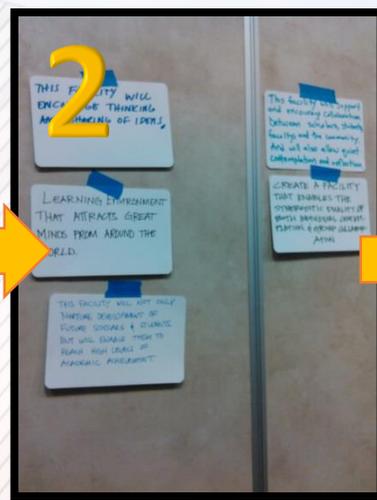
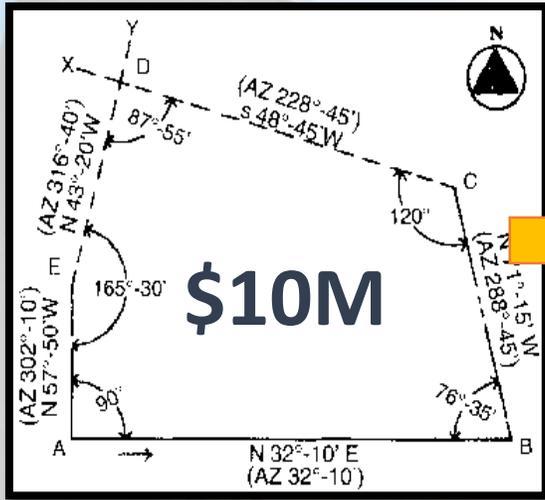
McLeamy Curve

© 2016 by Robert Warcup. All Rights Reserved.

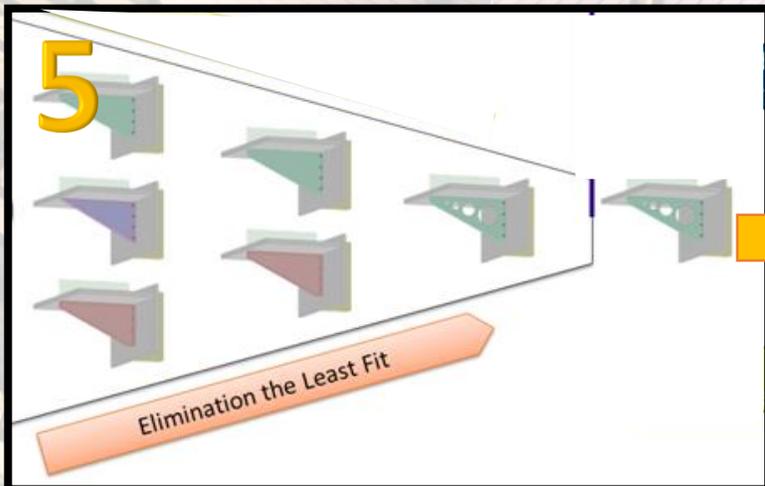
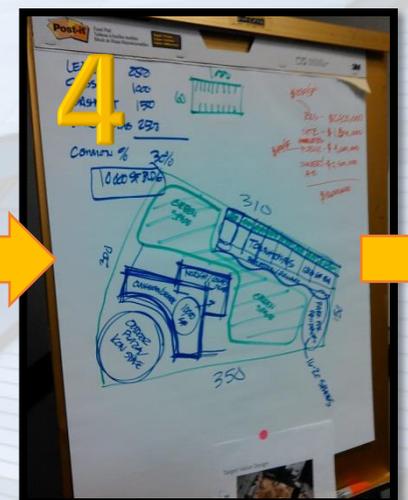
Owners, End-Users, Designers Contributing to Design



TOOL #3: Target Value Design



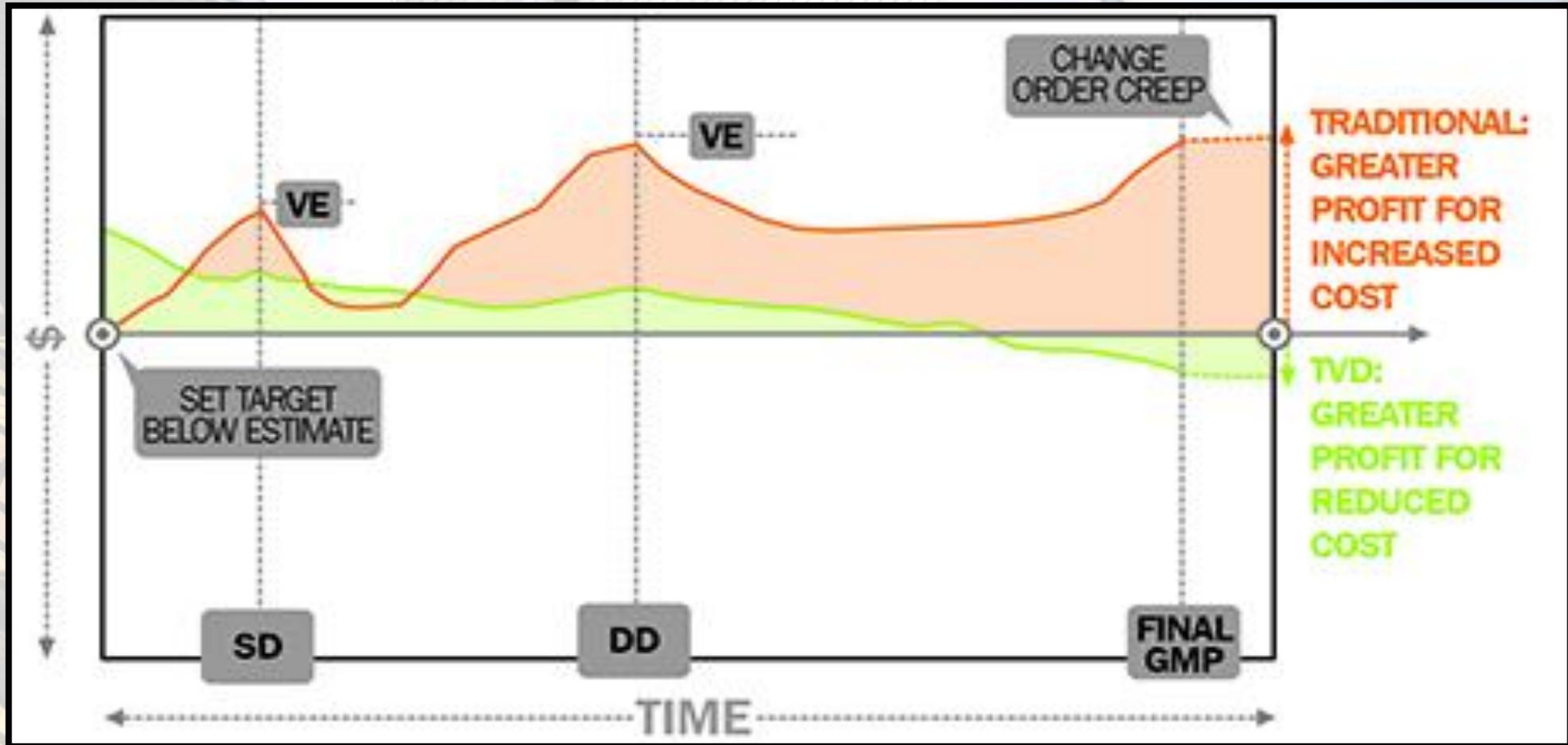
| BIG IDEAS | ANALYZE | PLAN | DESIGN | CONSTRUCT |
|-----------------------------------|---------|------|--------|-----------|
| INDOOR/OUTDOOR | | | | |
| DESIGN SCALE | | | | |
| PEOPLE HOME | | | | |
| COURTYARD | | | | |
| SEP SOCIAL | | | | |
| NOURISHMENT | | | | |
| TRANSPARENCIES | | | | |
| IT/AV THAT WORKS | | | | |
| INDOOR LIGHT, DARK, QUIET & NOISY | | | | |
| CATERING/EXH. | | | | |



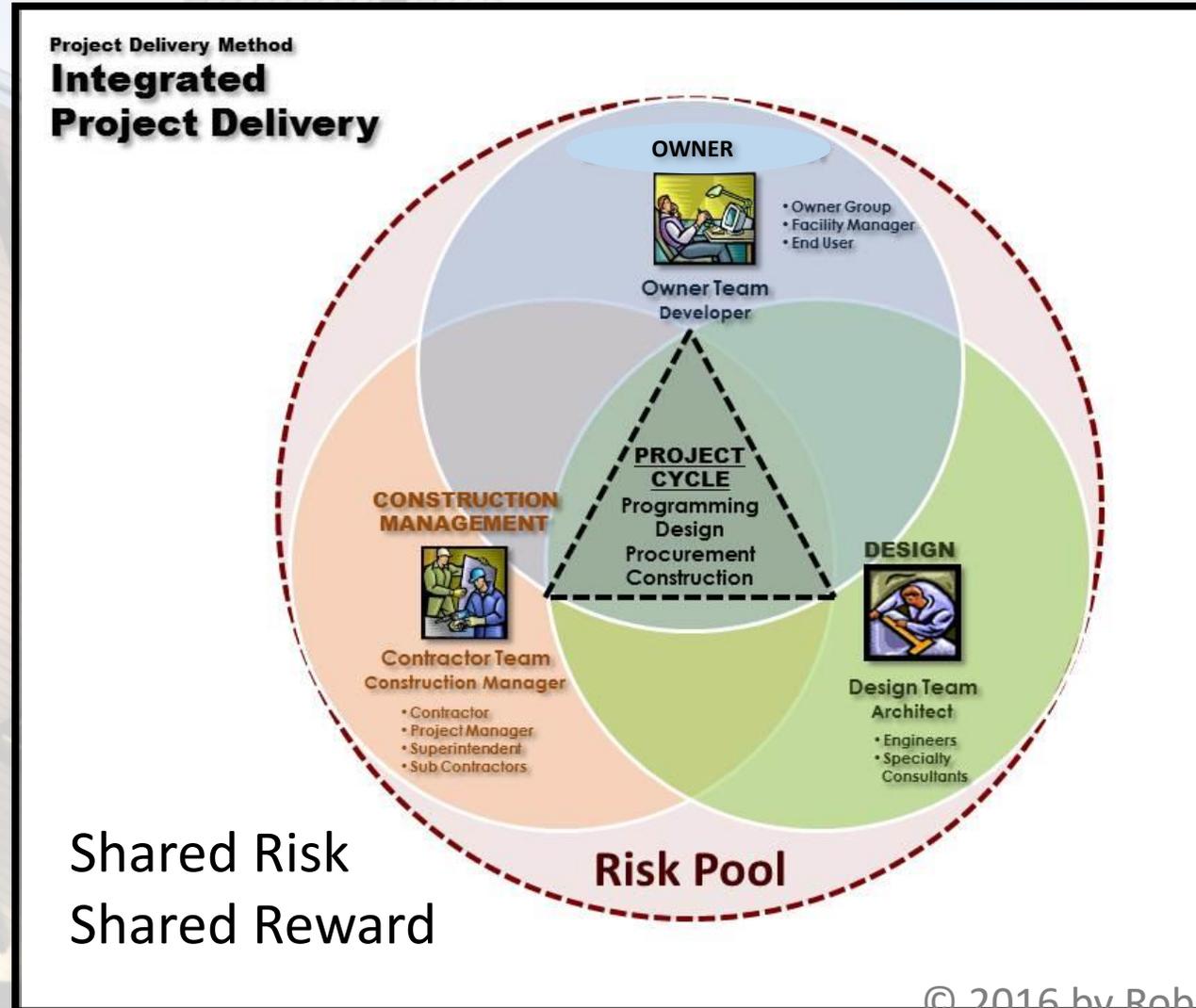
- TVD (Trade) Clusters:**
- 6 Mechanical & plumbing (17%) - \$1.7M
 - Electrical (14%) - \$1.4M
 - Foundation & structure (12%) - \$1.2M
 - Envelope including roof (20%) - \$2.0M
 - Hardscape/landscape (10%) - \$1M
 - Framing, drywall, millwork (12%) - \$1.2M
 - Interior finishes (flooring, fixtures, furniture) (10%) - \$1M
 - Contingency (5%) - \$0.5M
 - Total (100%) - \$10,000,000
- Under Budget**



Target Value Design & Integrated Project Delivery



Integrated Project Delivery (IPD)



Summary & Potential Results



Lean Tools

- Last Planner System (LPS)
- Value Stream Mapping (VSM)
- One-Piece Flow
- Just-in-time (JIT)
- Spaghetti Diagrams
- 5 Whys/Fishbone Diagram
- Choosing by Advantages (CBA)
- Integrated Project Delivery (IPD)
- A3 Reports
- Target Value Design (TVD)
- 5S and much more

Source: McGraw Hill Construction Research



A New Paradigm

Identify the **gap** between what you want to achieve vs. what you actually achieve on your projects on a regular basis.



Current State

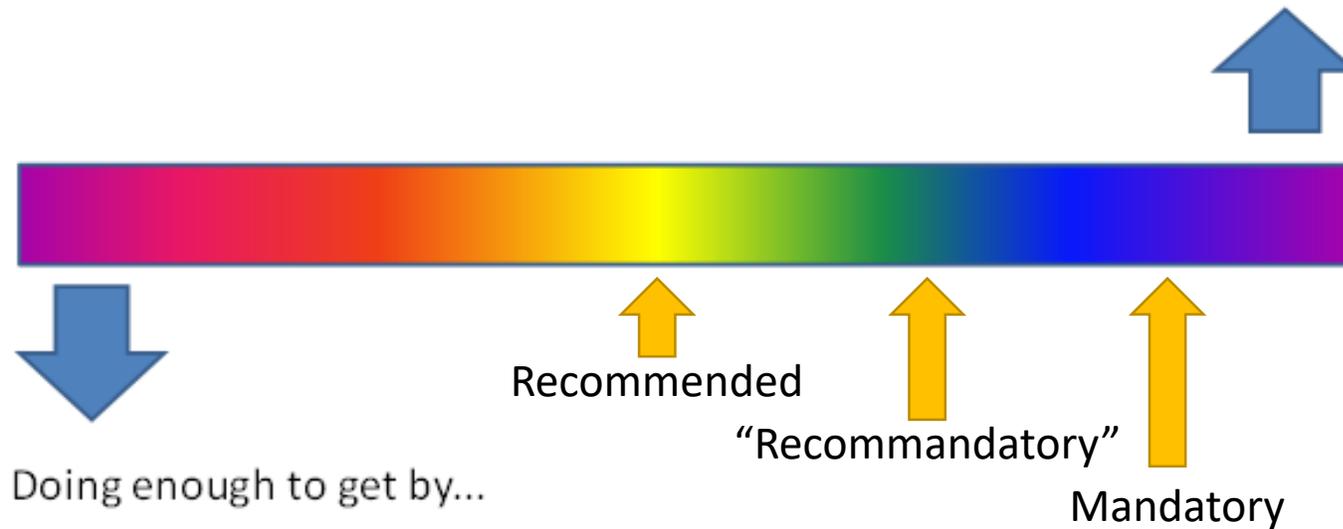
Desired State

We need to be willing to try something different

Lean Commitment

The commitment continuum

Consistently giving their all, routinely going “above and beyond” to deliver.



- Lean is **NOT** instantaneous
- Lean tools don’t make a company lean, only lean thinking does
- Management “support” won’t cut it
- Management must **DRIVE** lean!
- Eliminate the fear of failure

Lean Trainings

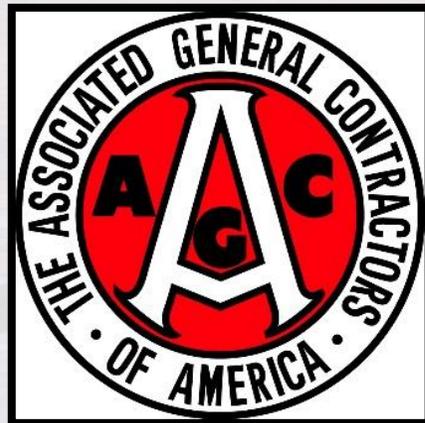
- Simulations
 - Dice – Parade of Trades
 - Lego – Villego
 - Block Tower
- Time & Motion Studies
- On-Site Pull-Planning
- On-Site Trainings
- On-Site Consulting
- Lean Tool Trainings



We need to be willing to try something different

Learning Opportunities

- Trainings
- Education
- Simulations
- Consulting



Lean Summary

- 8 Wastes Storytelling (DOWNTIME)
- Lean Tool #1: Value Stream Mapping
- Lean Tool #2: Last Planner System
- Lean Tool #3: Target Value Design

Do the right things for the right reasons and the results will follow!



Thank You

Rob Warcup

Robert.warcup@uvu.edu

801 502-2023 cell



Start
Your Lean Journey

© 2016 by Robert Warcup. All Rights Reserved.