Introduction to Lean Construction: Work Structuring and Production Control

Presented by the

Lean Construction Institute

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Presented at

UNIVERSITY OF Cincinnati

Cincinnati, Ohio

April 20-21, 2006

www.leanconstruction.org

What has changed Manufacturing, and sharply pushed up productivity, are new concepts. Information and automation are less important than new theories of manufacturing, which are an advance comparable to the arrival of mass production 80 years ago. Indeed, some of these theories, such as Toyota's "lean manufacturing", do away with robots, computers and automation.

Peter Drucker, "The Economist", pg 12, November 3, 2001.

Objectives of LCI

- To develop theory and tools for understanding and managing the way work is done throughout the project delivery process, and
- To support implementation and dissemination.

Seminar Objectives

- Understand the theoretical basis of the Lean Project Delivery System.
- Understand its language, essential features, principles, tools and techniques.
- Make clear the primary differences between the Lean Project Delivery System and current practice.
- Encourage you to take action.

What is this thing called "LEAN"?

- Not mass, not craft. A third form of production system design.
- The Lean Ideal
  - Meet requirements of a unique customer
  - Deliver it instantly
  - Maintain no inventory
- "Give customers what they want, deliver it instantly, with no waste."

Lean Production Goals

Deliver the product, while…

maximizing value *(give the customer what they need when they need it)* and

minimizing waste *(eliminate anything not needed for delivering value)*, and

pursuing perfection *(never stop striving to better achieve the lean ideal)*

Range of Projects & LCI

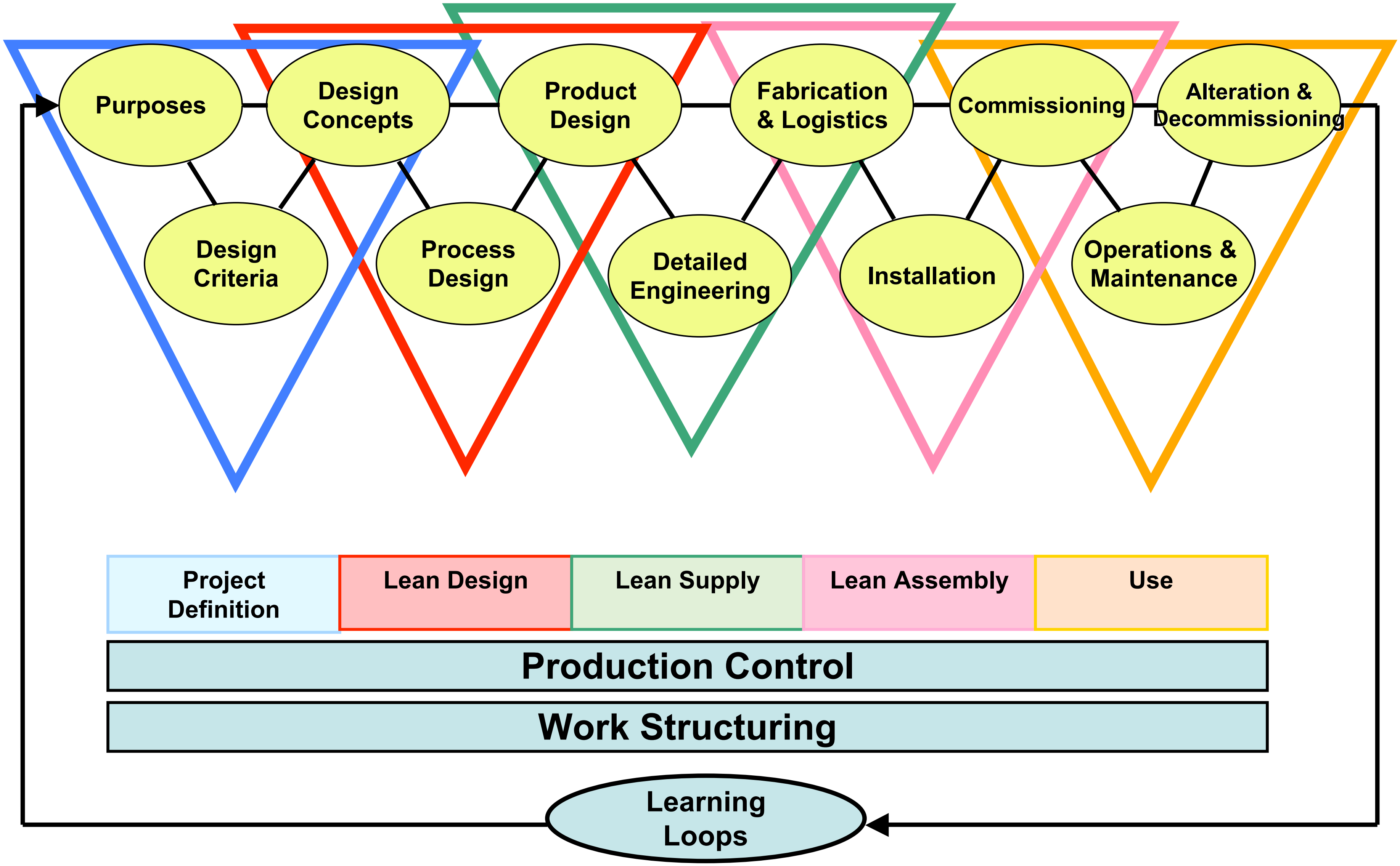
Stodgy — Understand the "Physics" of the Task — Dynamic

Design Systems to Support Lean Ideal

Conform Organization and Contracts

How do we manage projects now?

- Determine client requirements including quality, time and budget limits and design to meet them.
- Break project into activities, estimating duration and resource requirements for each activity and placing them in a logical order with CPM
- Assign or contract each activity, give start notice and monitor safety, quality, time and cost standards. Act on negative variance from standards
- Coordinate with master schedule and weekly meetings
  - reduce cost by productivity improvement
  - reduce duration by speeding each piece or changing logic.
  - improve quality and safety with inspection and enforcement


Purposes
Design Concepts
Product Design
Fabrication & Logistics
Commissioning
Alteration & Decommissioning
Design Criteria
Process Design
Detailed Engineering
Installation
Operations & Maintenance
Project Definition
Lean Design
Lean Supply
Lean Assembly
Use
Production Control
Work Structuring
Learning Loops

Agenda

- **Start up**
- **Work Structuring/Production System Design**
  - **Airplane Simulation**
  - **Case Studies in Design of Fabrication Systems: Malling and SpanCrete**
  - **Case Studies in Design of Site Installation Systems: Brazil (Pereira)**
  - **Case Study in Design of Supply Systems: Hollow Metal Doors (Boldt)**
- **The Physics of Production-Work Flow**
  - **The Parade of Trades Simulation**
- **The Physics of Coordination**
  - **Workflow loop**
- **Production System Control using the Last Planner® System**
  - **Pull scheduling**
  - **Lookahead planning**
  - **Reliable promising**
  - **Learning**
- **More about Lean Project Delivery (if time available)**
- **Implementation/Organization Structuring**
- **Research directions**
- **Wrap up**

The Airplane Game

An exercise in production system design

The Airplane Game

At your table, discuss and answer the following questions and have a spokesperson report for your group. You have 15 minutes.

1. What are the key points or lessons for you?
2. How might these apply to designing and building?

Lean Production Techniques in the Airplane Game

- Release work (materials or information) from one workstation (specialist) to the next by pull versus push
- Minimize batch sizes to reduce cycle time.
- Make everyone responsible for product quality
- Balance the workload at connected workstations
- Encourage and enable specialists to help one another as needed to maintain steady work flow (multiskilling)

More Lean Production Techniques

1. Stop the line rather than release bad product to your ‘customer’.
2. Minimize changeover (“setup”) time to allow one piece flow.
3. Make the process transparent so the state of the system can be seen by anyone from anywhere.

Goals for Production System Design

- Match throughput rate (TH) to demand rate
- Minimize cycle time
- Reduce WIP to the minimum needed to maintain throughput
- Minimize resources required

Production Systems in Construction

- The physical characteristics of production tend to be ignored.
- Variability in production systems is not taken into account.
- Production is largely uncontrolled.
- Lack technical knowledge about production; e.g., work flow reliability, defect rates, process and operation designs.
- There is no systematic process for learning from experience.
- Extreme fragmentation, even within single companies.
- Central control fantasy—push system.

Ohno’s 7 Types of Waste

- Defects in products
- Overproduction of goods not needed
- Inventories of goods awaiting processing or consumption
- Unnecessary processing
- Unnecessary movement of people
- Unnecessary transport of goods
- Waiting by employees for process equipment to finish work or for an upstream activity to complete.

Key Terms

- **Work Flow-the movement of information and materials through networks of interdependent specialists.**
- **Release of work - making work available to the next specialist.**
- **Dependence - waiting on release of work.**
- **Variation - the range of work completed each day or week.**
- **Buffer - a verb: "to isolate one activity from the next."**
- **WIP - Work in process.**
- **Point Speed - how fast each assignment or activity is completed.**
- **Throughput - the amount of the project completed each period.**
- **Capacity - amount of work that can be done by the specialist, related to productivity.**
- **Push - Advancing work based on central schedule**
- **Pull - Signaling for components of work to arrive when they will be required.**

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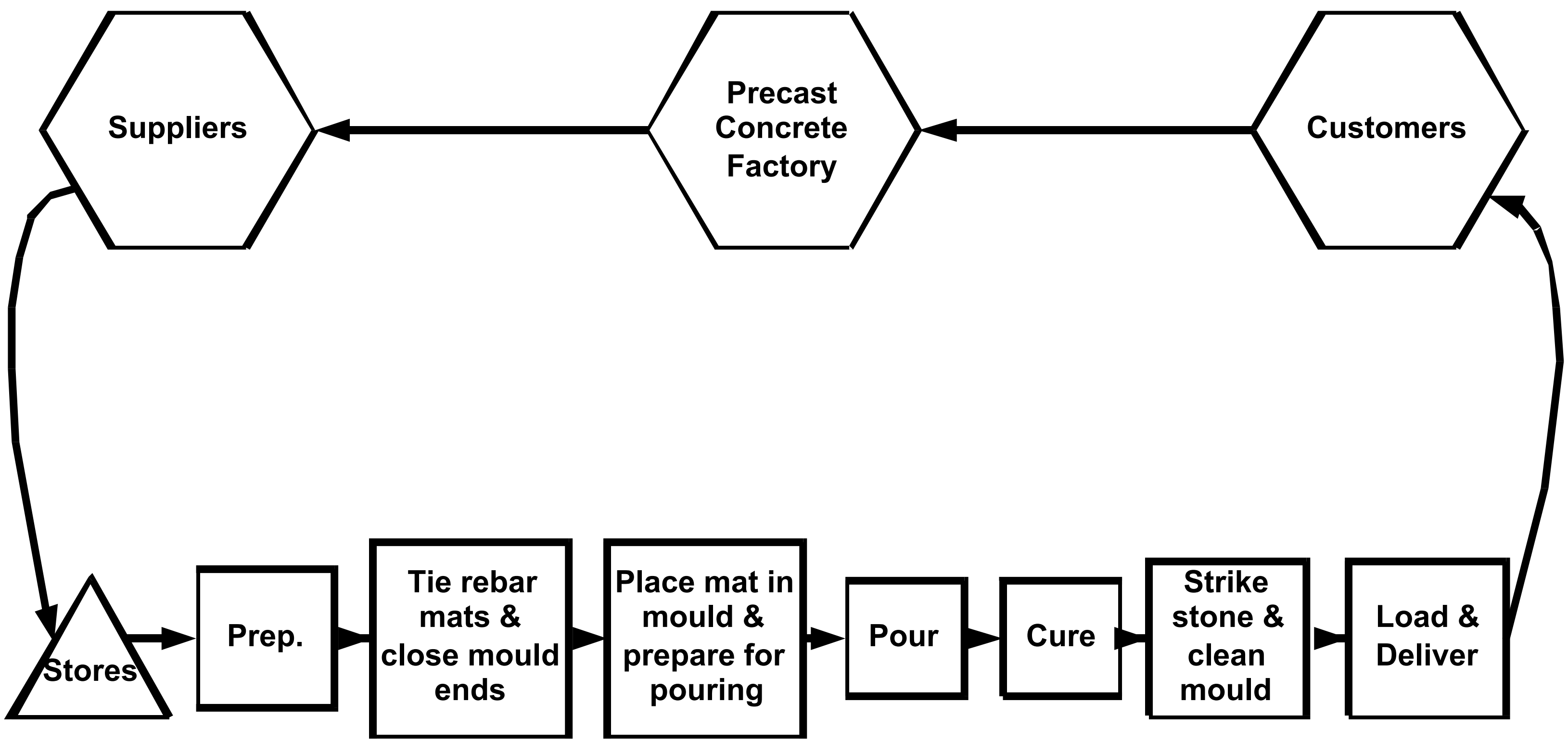
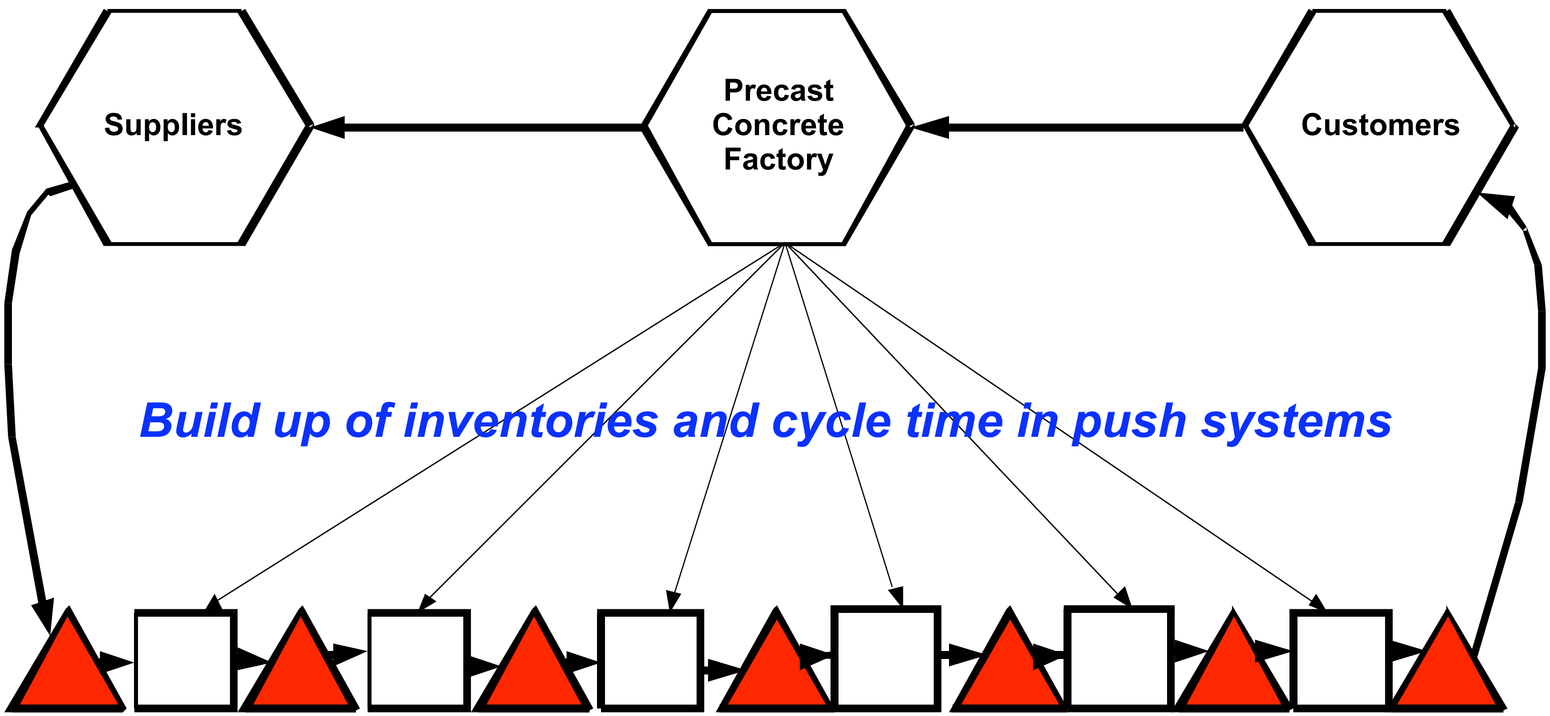
XYZ Production Cell: Shear Walls

Process Chart



XYZ Production Cell: Shear Walls

Process Chart



Production System Design Exercise: How apply pull, one piece flow, etc.?

How would you improve a process for fabricating precast concrete shear walls from 3.2 walls average per day to match a demand rate of 9 walls per day, without changing technology or manning? How would you match production sequence and rate to customer demand? How would you assure availability of information and materials needed to support the production plan?

Fabricating precast concrete shear walls: process as found

- Foreman receives drawings and collects materials
- Foreman gets rebar cut and bent at rebar department
- Foreman has ironworkers tie rebar cages
- Foreman has carpenter shop make end pieces for form from wood
- Laborers place cage in form and install embeds.
- Foreman has carpenter come close ends of form
- Laborers seal form
- Foreman orders concrete from batch plant
- Laborers place concrete in form
- After concrete has cured, laborers strike the form and load the wall section onto trailer
- 7 laborers and 1 foreman are assigned to shear walls, plus part time from carpenter, et al., amounting to 12 worker days per day
- Average production rate is 3.2 shear walls per day

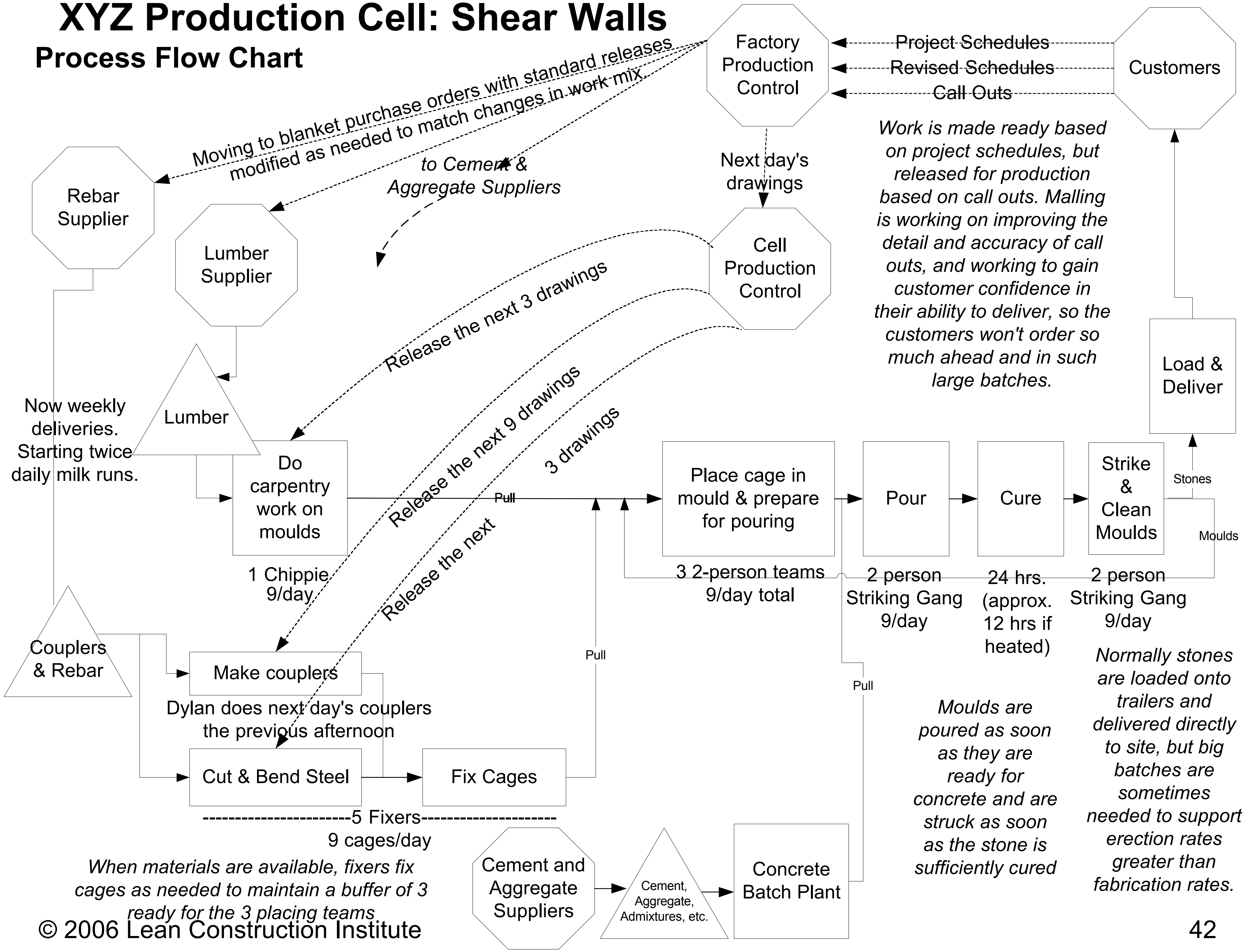
Shear Walls: Removing Obstacles to Better Performance

- Refurbished cut and bend plant to make them self sufficient
- Moved materials to the workplace to reduce unnecessary movement
- Got them trailers to move stones out
- Cleared work area
- Played Airplane Game with work force and adapted lessons
- Got additional chains for crane
- Set up carpenter in cell location

		1	2	3	Night	Early Shift	1	2	3	Night	Early Shift	
Cut & bend steel bars & make mould ends	AB	C	D	E			F	G	H			
Fix rebar cage	A	B	C	D			E	F	G			
Place cage & pour		A	B	C			D	E	F			
Cure					A,B,C					D,E,F		
Strike & clean mould						A,B,C					D,E, F	

XYZ Production Cell: Shear Walls

Process Flow Chart



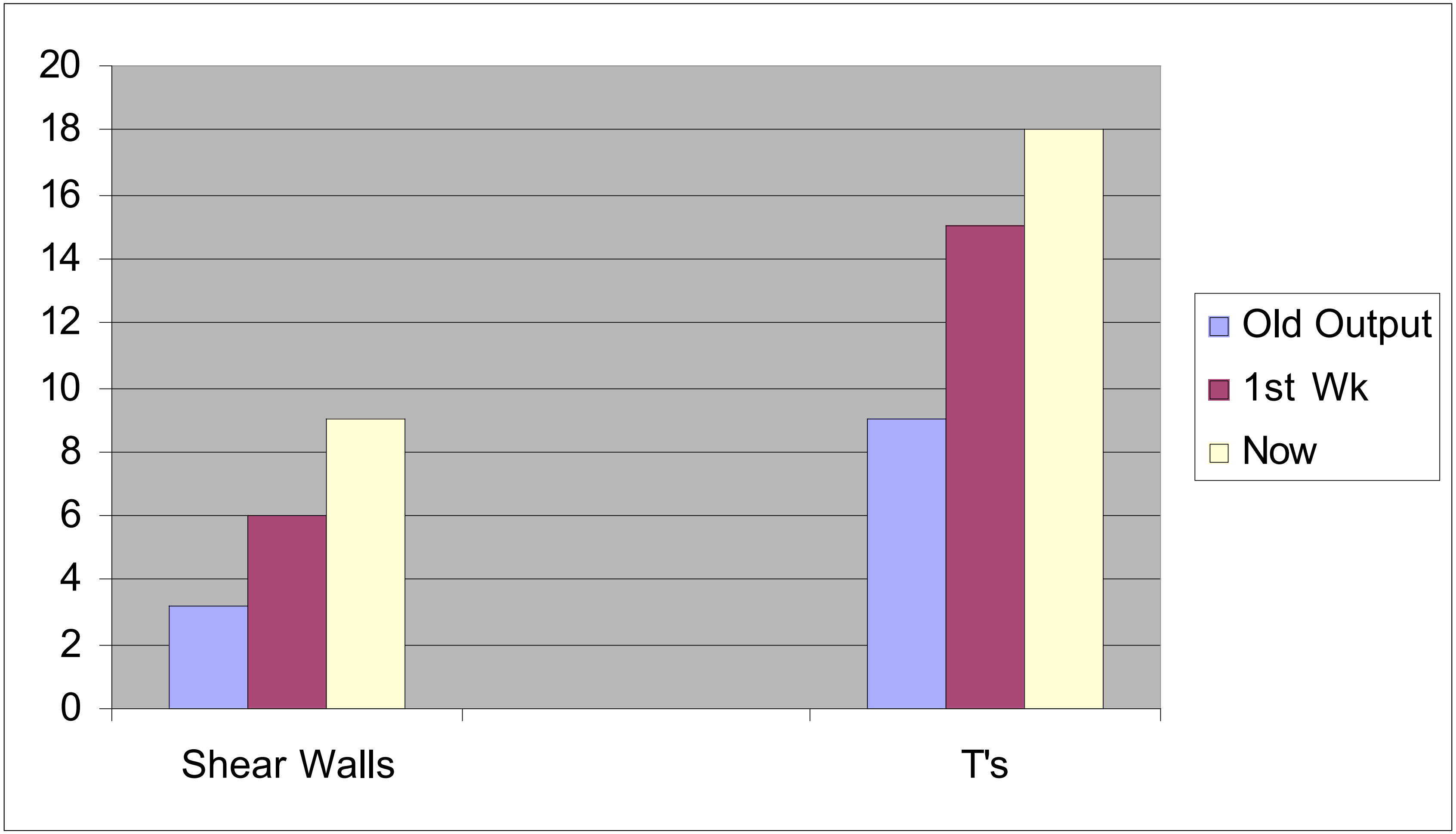
Moving Towards Self Managing Production Cells: Guidelines

- Follow the sequence.
- Inspect your own work.
- Don’t get more than one step ahead of your ‘customer’— do one at a time.
- Help others maintain work flow.
- Make suggestions to improve safety, product quality, productivity, or quality of work life.

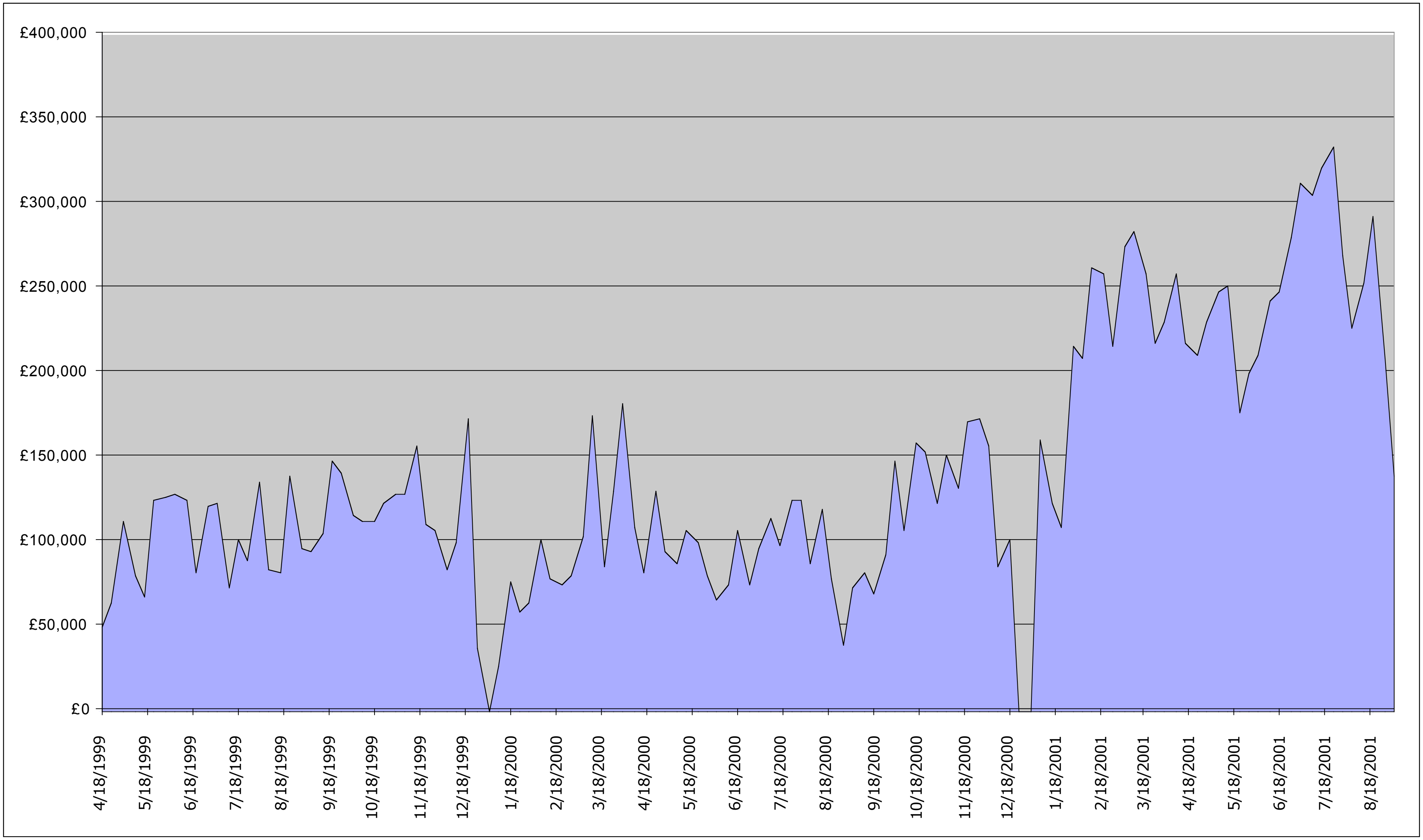
Implemented Suggestions from the Work Force

- Simplified bearers
- Poly vs steel boxes
- Truck mixer
- Reallocated tasks from striking crew so they could hit their 30 minute window
- Reassignments: Medium experienced operative placed 3 cages per day with minimal supervision
- Cell meetings and clearly assigned responsibilities
- Workers self initiated area cleanup

Improvement in Throughput & Productivity



Malling Revenue



Product Mix

Process Pattern	One of a Kind or Few	Low Volumes: many products	High Volumes: several major products	Very High Volumes: Standard product (Commodity)	*Management Challenges*
Very jumbled flow; process segments loosely linked	Project Job Shop				Scheduling; materials handling; shifting bottlenecks
Jumbled flow; but a dominant flow exists		Batch Flow			
Line flow: worker paced			Line Flow		Worker motivation; balance; maintaining enough flexibility
Line flow: machine paced			Line Flow		
Continuous flow, automted and rigid flow, process segments tightly linked				Continuous Flow	Capital expenses for big chunk capacity; tecnological change, materials mgmt; vertical integration
Management Challenges	Bidding; delivery; product design flexibility		Quality (Product Differentiation); flexibility in output volumes	Price	

Spancrete's Lean Approach to Manufacturing (SLAM)

Work Group	Status	Results	Focus
Waukesha Wet Cast	Launched (now on 6th improve- ment cycle)	27% cost reduction; 67% increase in productivity	5S in shop; TPM; cycle time reduction in shop from pull techniques, pouring concrete asap. Now working on yard operations
Valders Wet Cast	Launched (on 5th cycle)	100% increase in tees, from pours every 2 days to daily pours	5S in shop; cycle time reduction. Current goal: turn 2 beds of insulated plank/day.
Crystal Lake Plank	Launched (on 4th cycle)	18% increase in productivity, greater flexibility to changes in demand	Changed from stack casting to single piece flow. Now working to reduce changeover time from 8-inch to 10-inch plank.
American Concrete Pipe Specialty	Launched (on 3rd cycle)	82% reduction in finished goods inventory	5S and pull techniques on outside operations; now implementing 5S on inside operations
Drafting & Engineering	Current		Admin 5S, info transfer from Sales, materials ordering

SLAM Accomplishments

- Throughput increased from 565,898 cu. ft. to 1,134,966 cu. ft.
- Direct labor hours per unit of output decreased from .174 to .162
- Raw material inventory turns increased from 17.14 to 25.15

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Apartments

Terra Brasilis	Vila do Sol
23 floors	23 floors

R
E
F
E
R
E
N
C
E

Lean w/o Autonomation

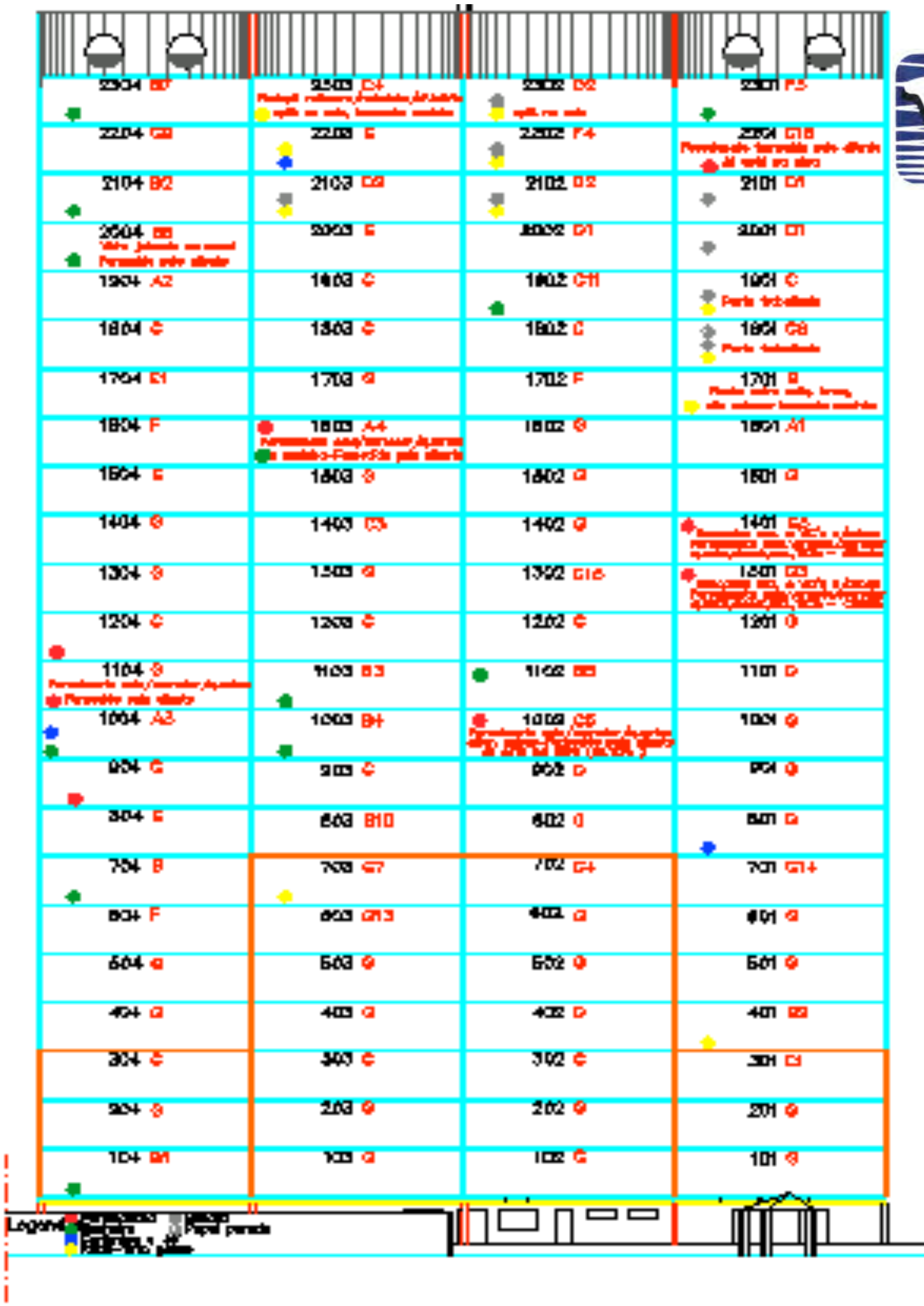
F
O
C
U
S

Opening: Jun/2005

Lean w/ Autonomation

Competitive advantage

Section of Vila do Sol with an annotation of the model for each apartment.
(April /04)
A1,A2,
A3,A4,
B1,B3,
B2,B4,B5,B6,
B7,
C,C1,C3,
C4,C5
D1,D2,
E1,
F,F3,F4,
G,G2,G3,
G7,G8,G9,
G10,G11,
G13,G14,
G15,
(Total 33/92)



Fibra
Construções Ltda

Competitive advantage
But production challenge

M Informática
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Toyota Production System

M
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D
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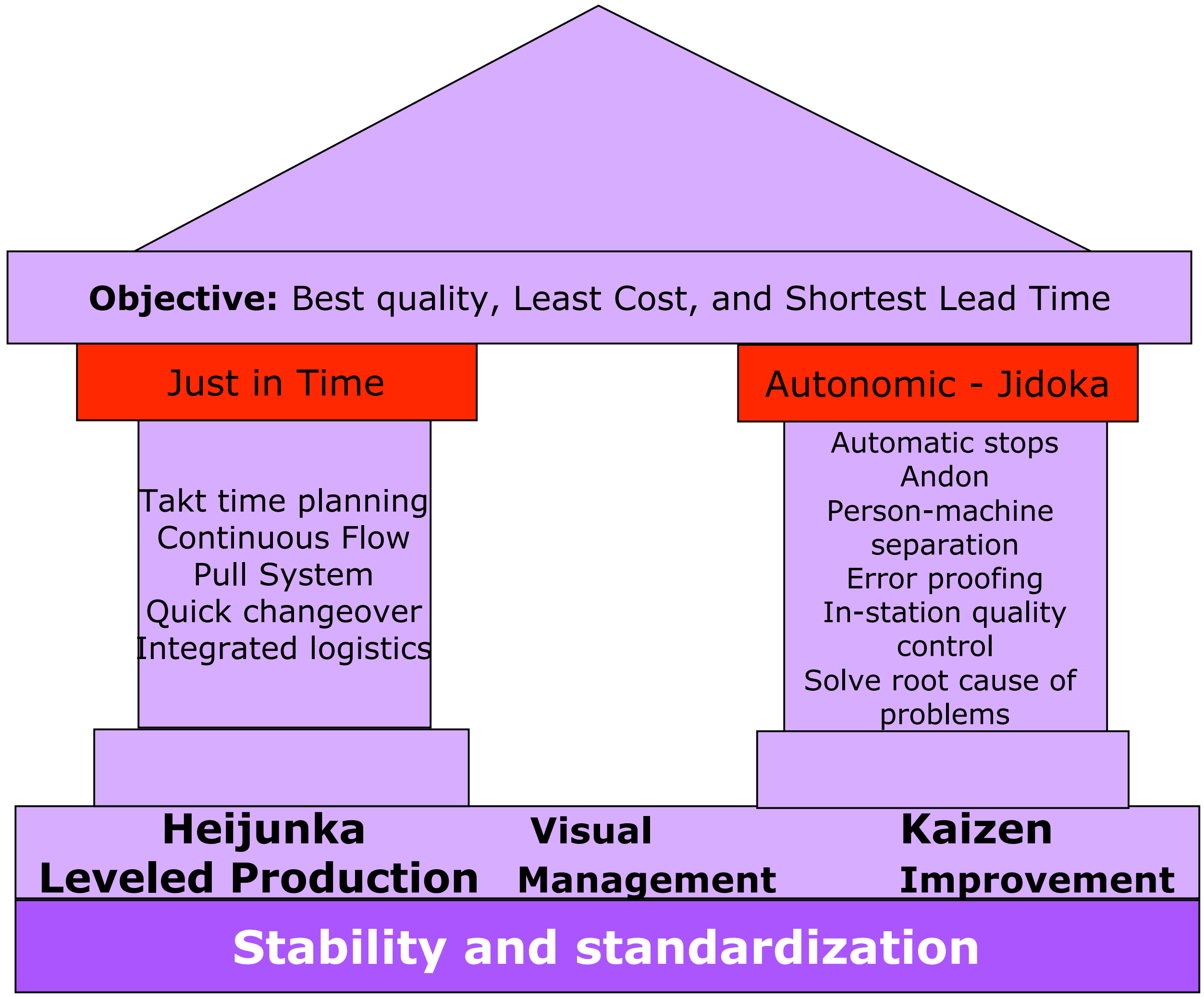
L



TOYOTA WAY

Two Pillars that support the Toyota Production System

1. Just-in-time
2. Autonomation, or "automation with a human touch”

“.. autonomic means making judgements autonomously at the lowest possible level; for example, when to stop production, what sequence to follow in making parts, or when overtime is required to produce the required amount.”

Ohno, Taichi. Toyota Production System - 1990.

“Autonomic” Self regulating, functionally independent.
Webster´s on-line dictionary

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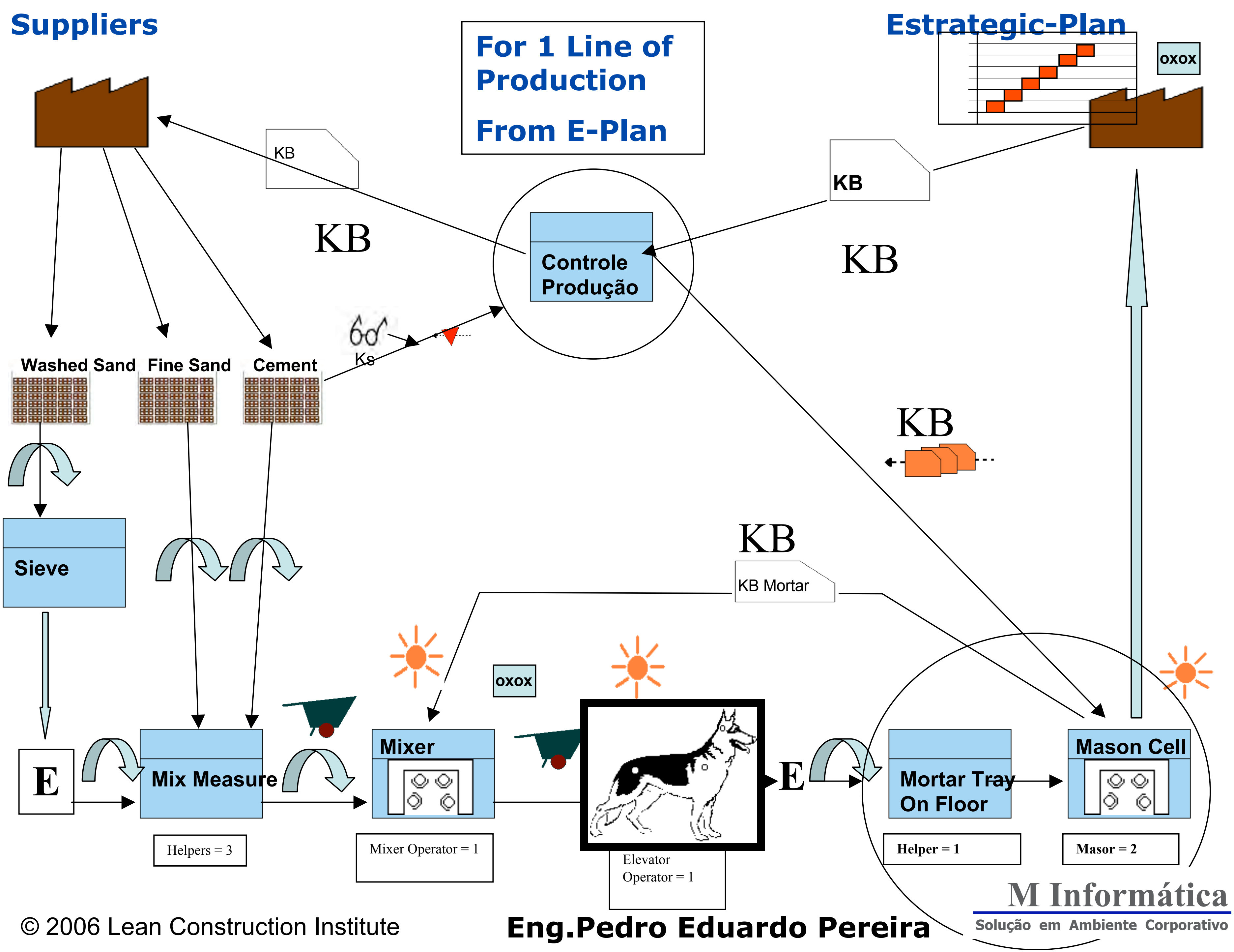

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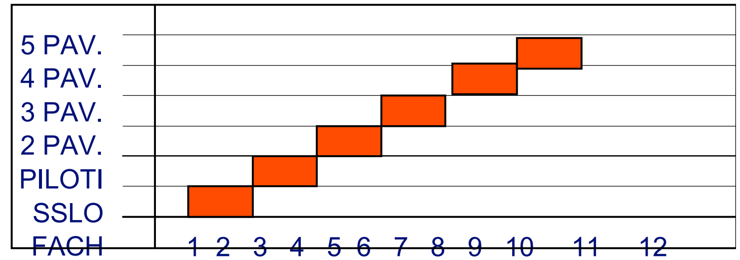
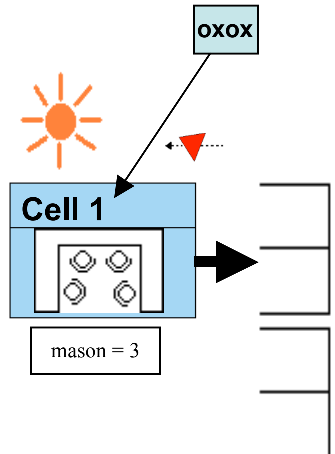
SHAFT

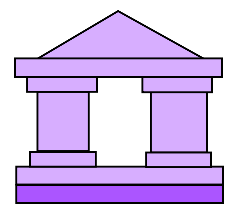




Inventory In process

Flow
Information
Material
people
process

Think like Toyota House for all levels



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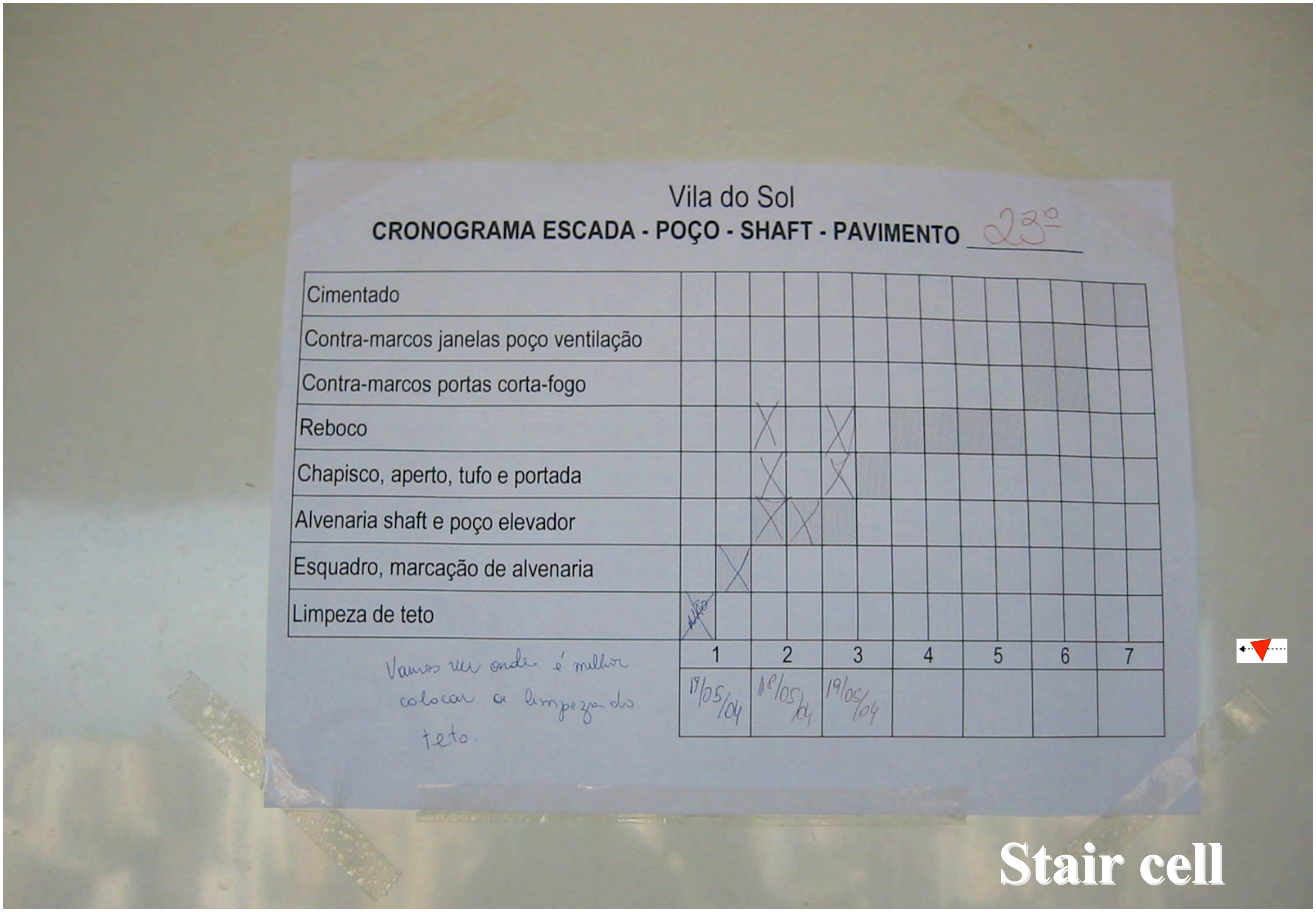
S T A N D A R D I Z E D

SEQUENCE AND FLOW (V. 2.0)

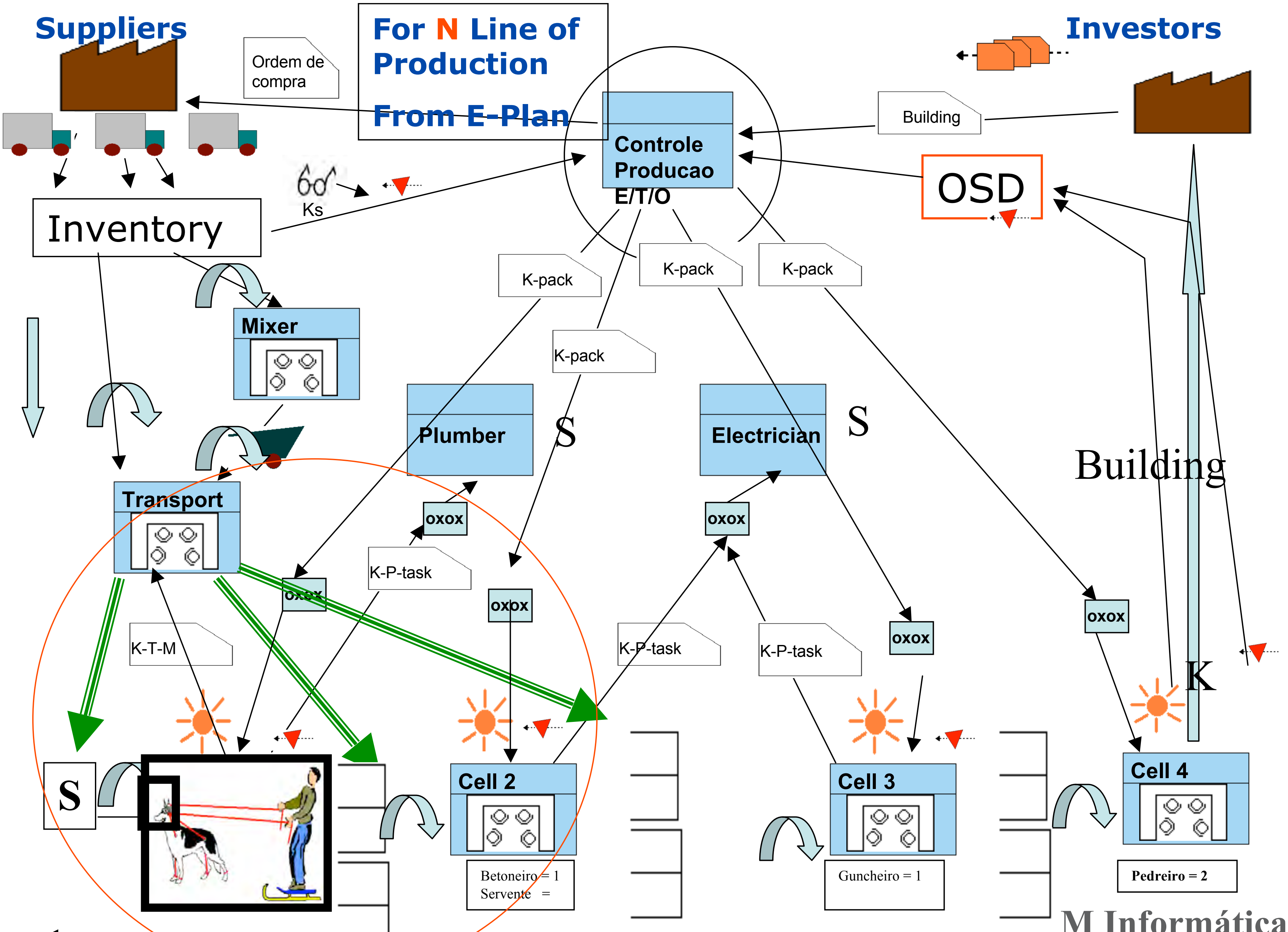
(IMPROVEMENT)

S T A N D A R D I Z E D



SEQUENCE AND FLOW - How is the dog running?

(V. 2.0) (**IMPROVEMENT**)



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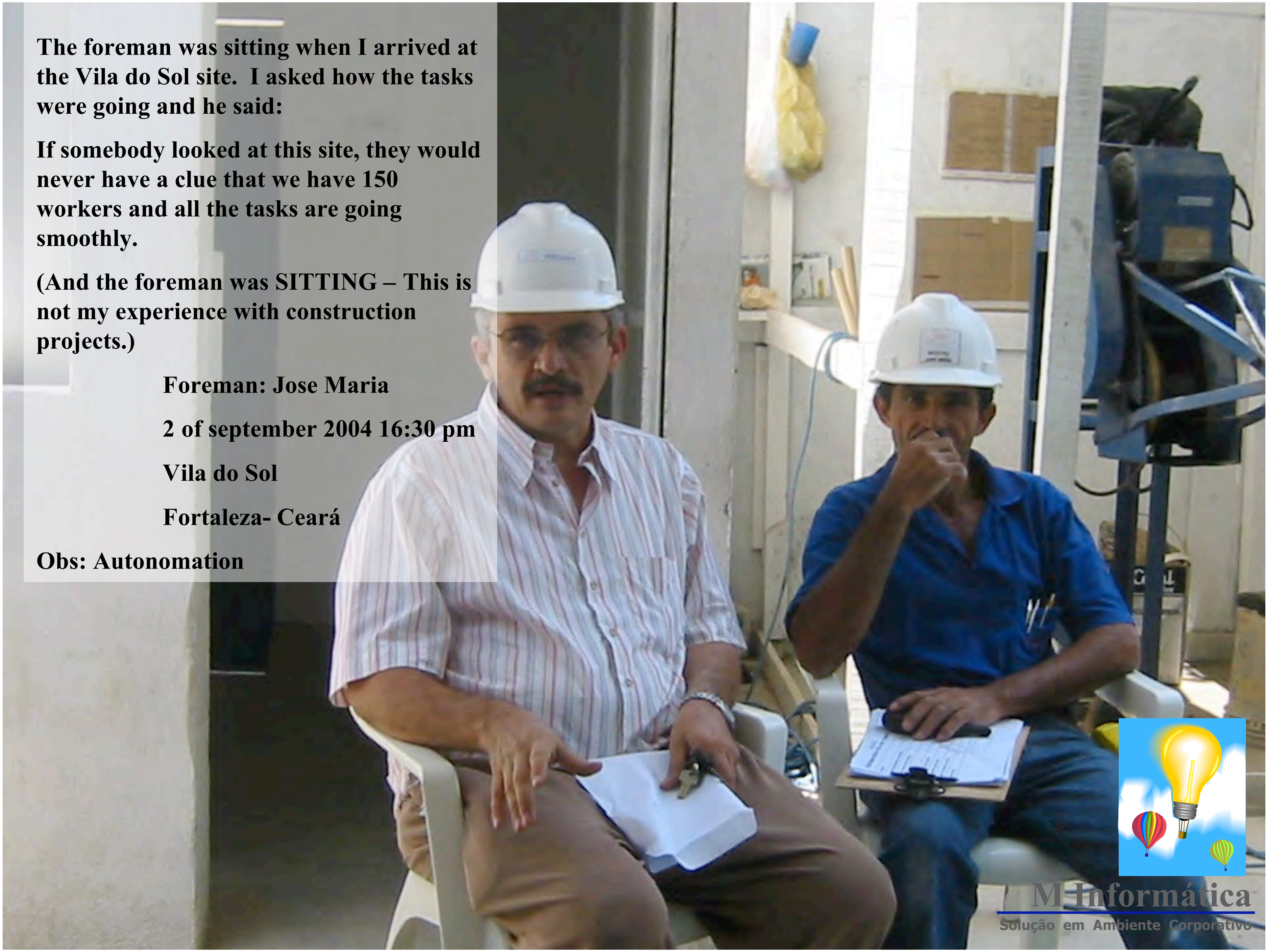

The foreman was sitting when I arrived at the Vila do Sol site. I asked how the tasks were going and he said:

If somebody looked at this site, they would never have a clue that we have 150 workers and all the tasks are going smoothly.

(And the foreman was SITTING – This is not my experience with construction projects.)

Foreman: Jose Maria

2 of september 2004 16:30 pm

Vila do Sol

Fortaleza- Ceará

Obs: Autonomation

M Informática

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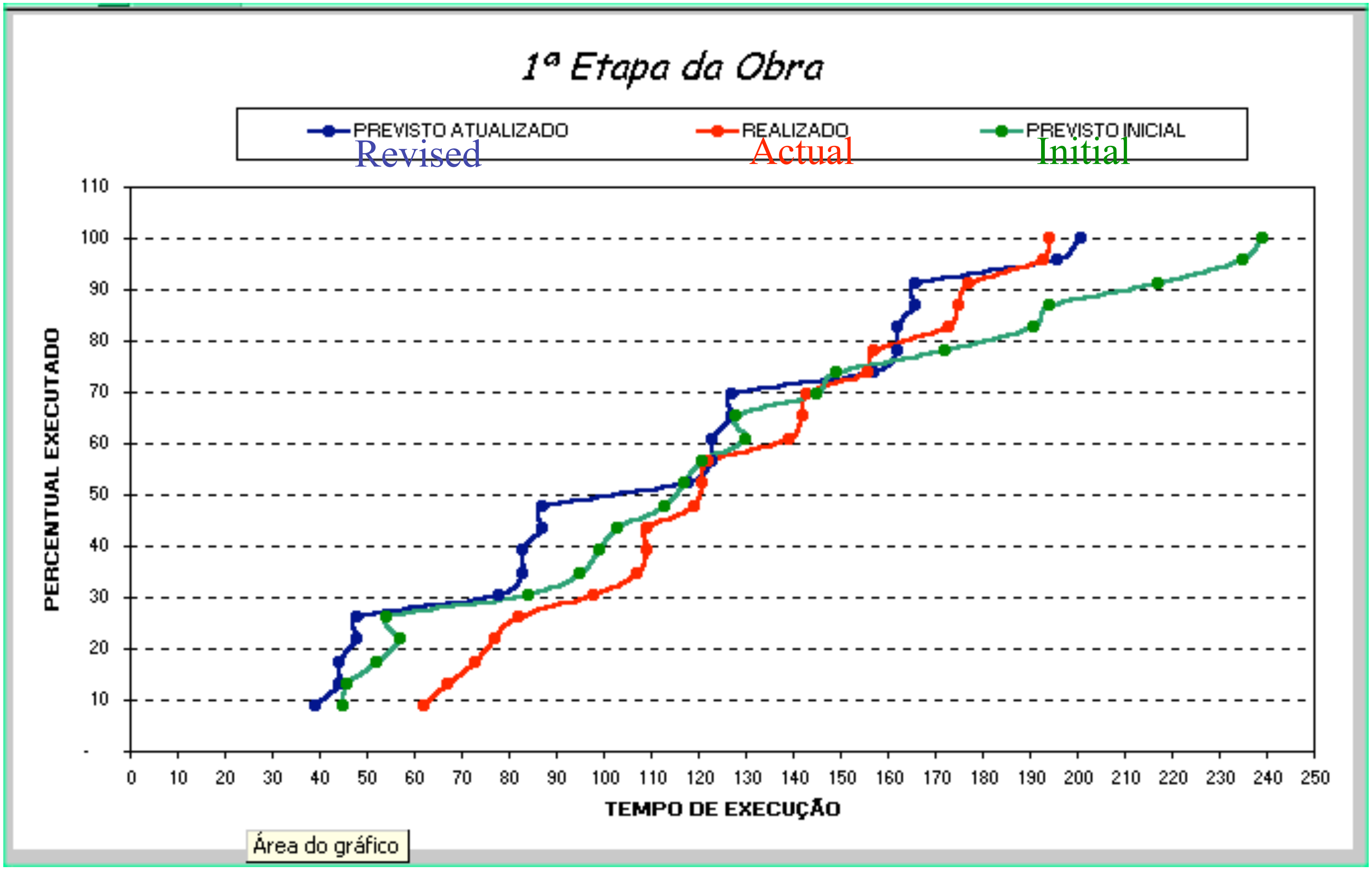
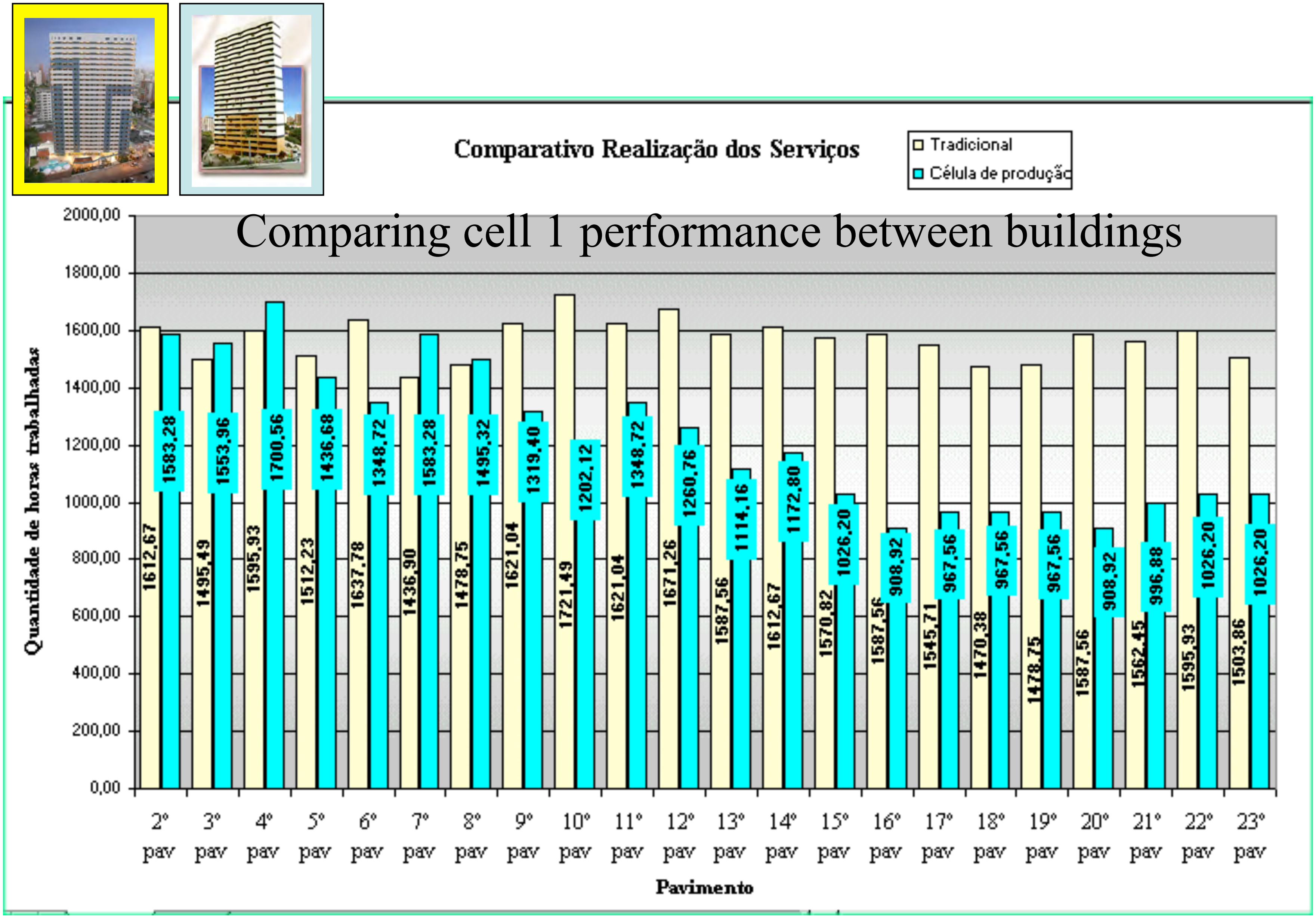
Cell 1 Phase Plan



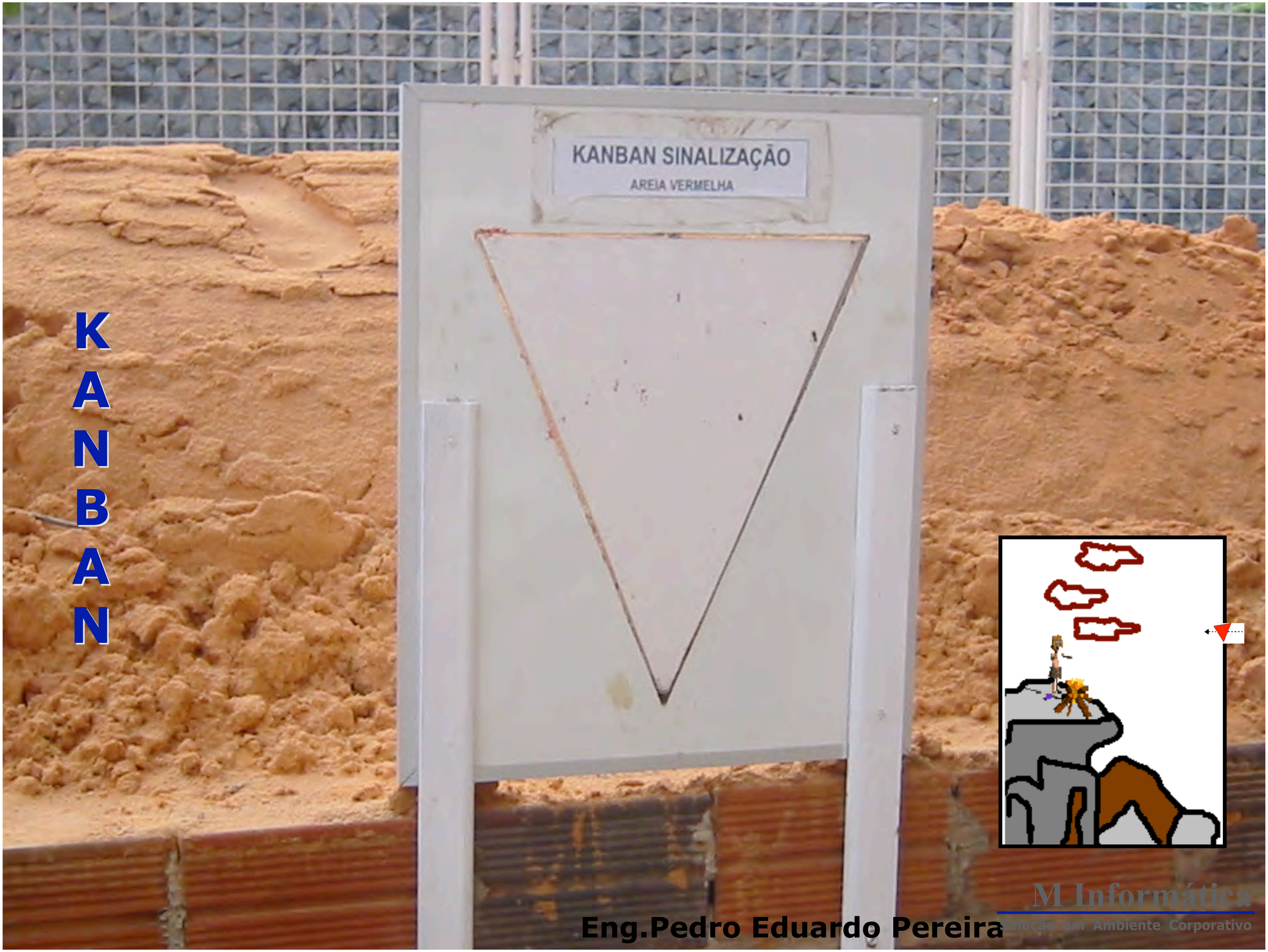
Comparing cell 1 performance between buildings




KANBAN CARDS
Quantities established to support standard production rates

Response time and quantities established for transport cell to support standard production rates

K
A
N
B
A
N



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KANBAN SINALIZAÇÃO
BRITA
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3 buttons

- Normal Operation
- We will stop in less than one hour
- Work Stopped

Signal Station on each Floor

Mason- Luiz José de Lima

3 buttons

Vila do Sol

A
N
D
O
N

Secretary Maruska Gomes Arruda

LIGHT PANEL FOR ANDON SIGNALS FOR EACH FLOOR

Learnings (Kaizen)

Before		After	
Light blue	Normal Operation	Light blue	Normal Operation
Yellow	We need help.	Yellow	We will stop in less than one hour
Red	Work Stopped	Red	Work Stopped

- At first, ANDON lights were a dangerous idea - inviting management to the work
  (**Ohno's great idea of a Pull system for a manager cell**).

- ANDON lights became a very good idea when management began to solve problems. Workers made more money. (New good problem is how to change the price)

- And so the lights' definition of use were adjusted to provide a warning for managers before a stop.

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The DNA of Toyota

1. All work shall be highly specified as to content, sequence, timing and outcome
2. Every customer-supplier interface must be direct, and there must be an unambiguous yes-or-no way to send requests and receive responses
3. The pathway for every product and service must be simple and direct
4. Any improvement must be made in accordance with the scientific method, under the guidance of a teacher, at the lowest level possible in the organization.

Work Structuring

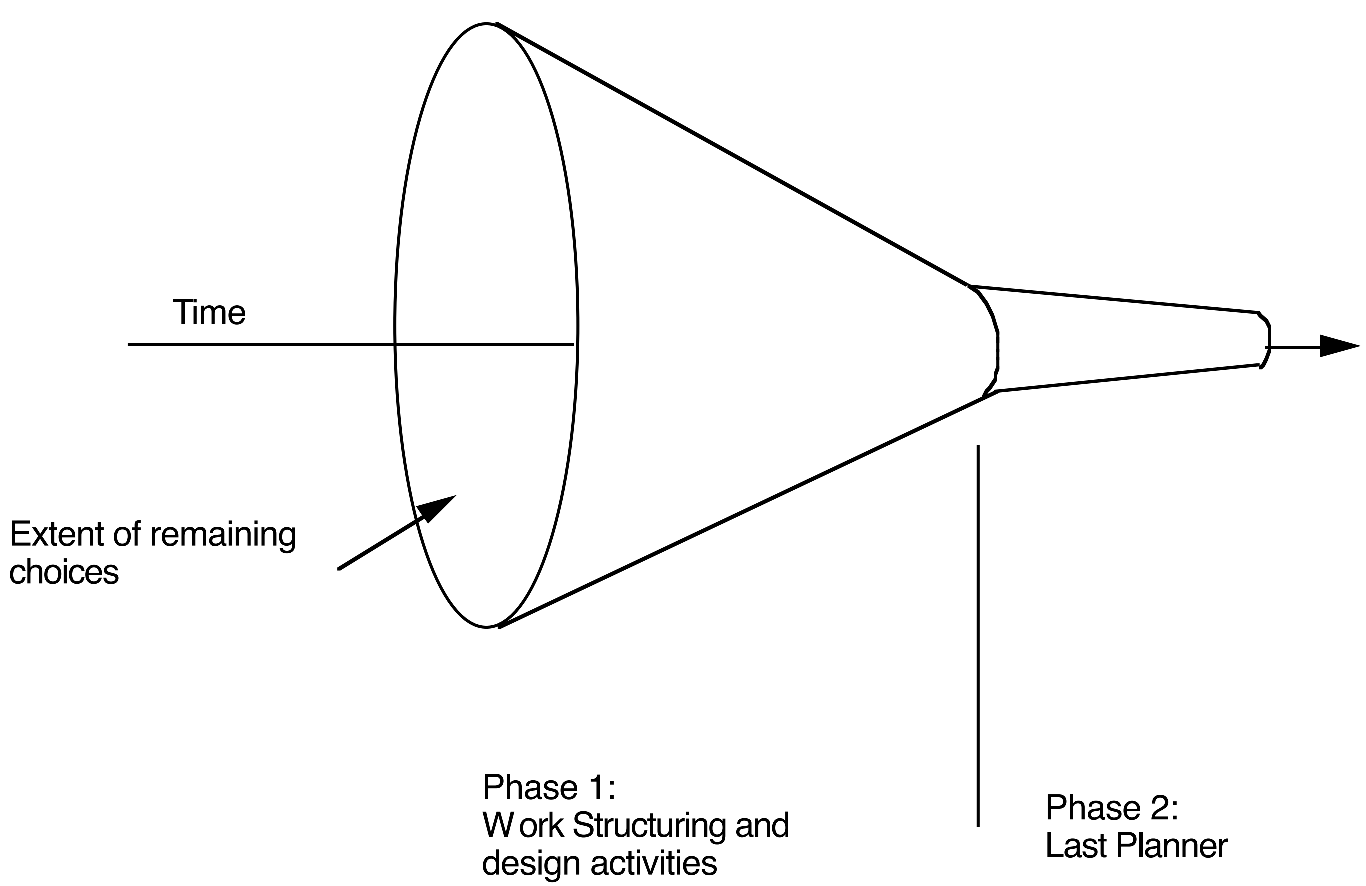
Work structuring is planning, aka process design. Planning starts with the design of the entire production system and goes all the way down to the design of individual operations. Process design changes to generate product-based value. Product design changes to generate process-based value and to eliminate waste.

Products of Work Structuring

- Global sequencing
- Project Organizational/Contractual Structure
- Supply Chain Configurations (how the project hooks to external production systems)
- Master Schedule & Phase Schedules
- Rough Cut Operations Designs; e.g., decision to cast-in-place vs precast, or use a tower crane vs rolling stock
- Detailed Operations Designs; e.g., how to form-rebar-pour basement walls

Work Structuring and Operations

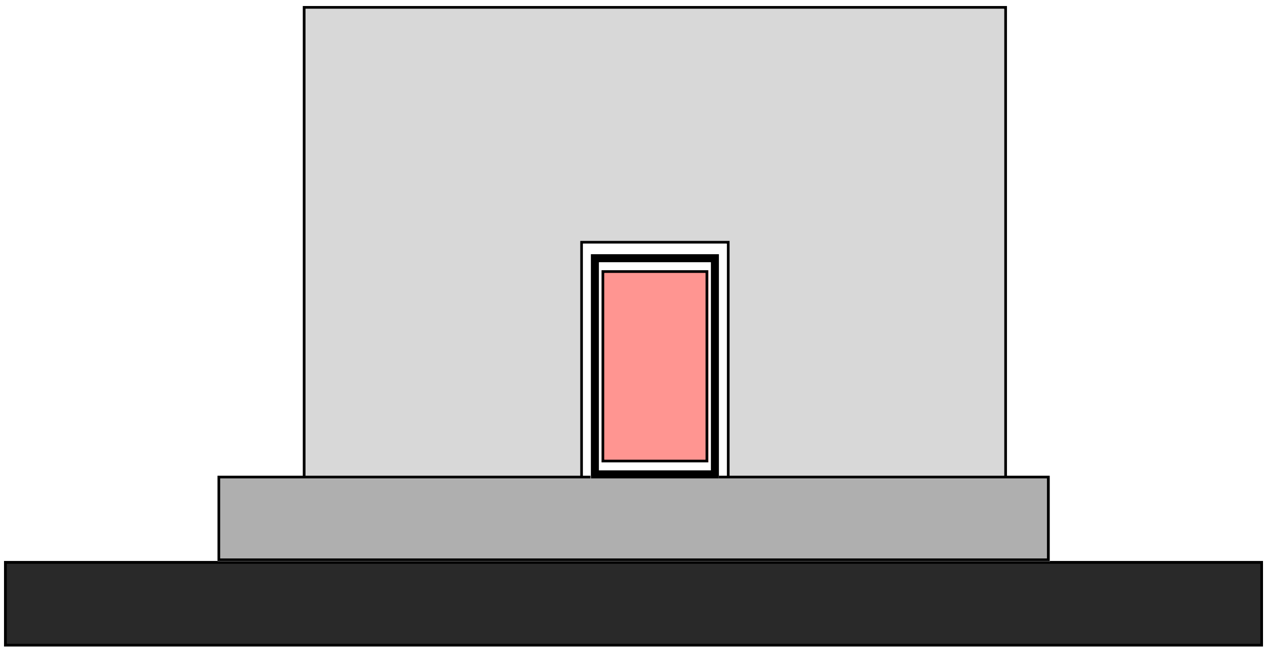
The extent of choices on the design of operations



Discussion questions

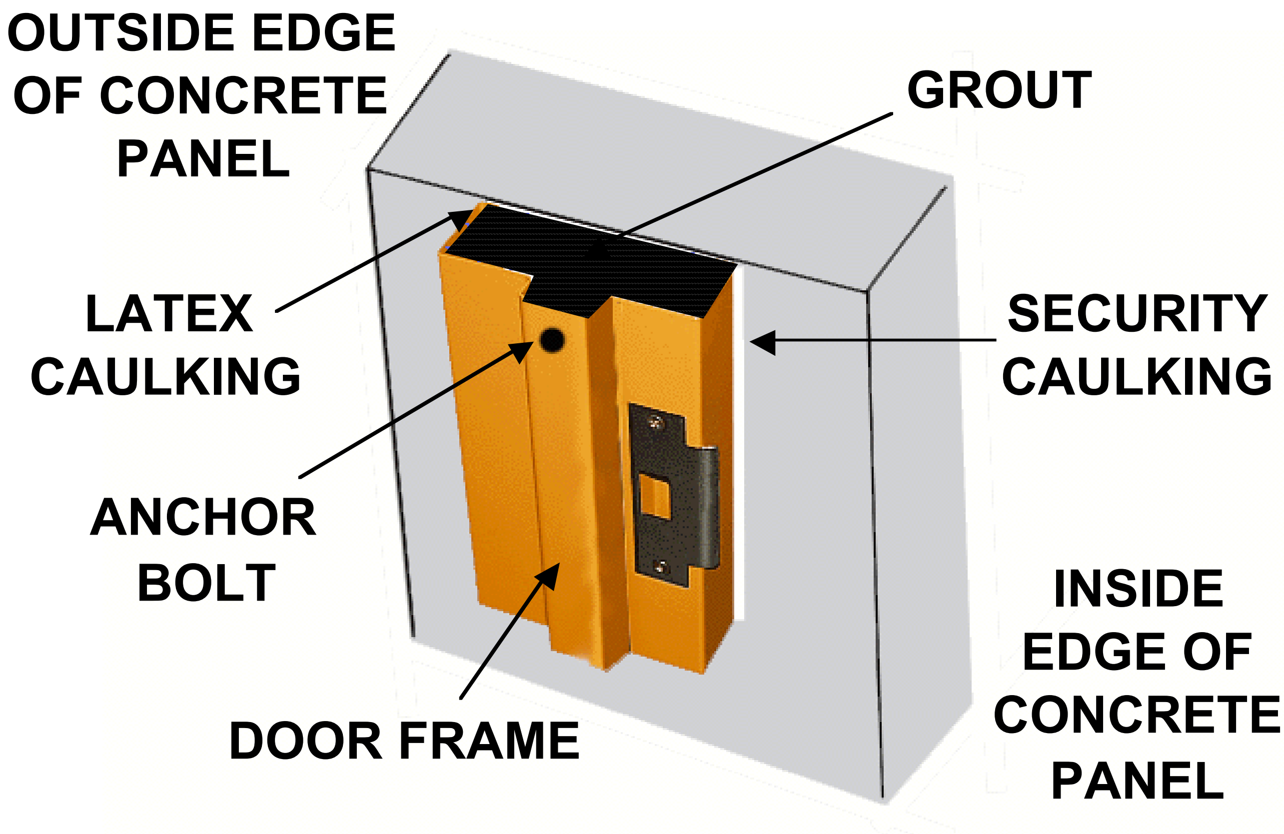
- Why did they do it the way they did?
  (What "organizing principle" was applied?)
- How would you do it if you were doing it right? Identify the new "organizing principle".

Building a Cell - The Big Steps



Foundation → Precast → Top Slab → Doors → Paint

3D View of Door Frame and Wall Panel

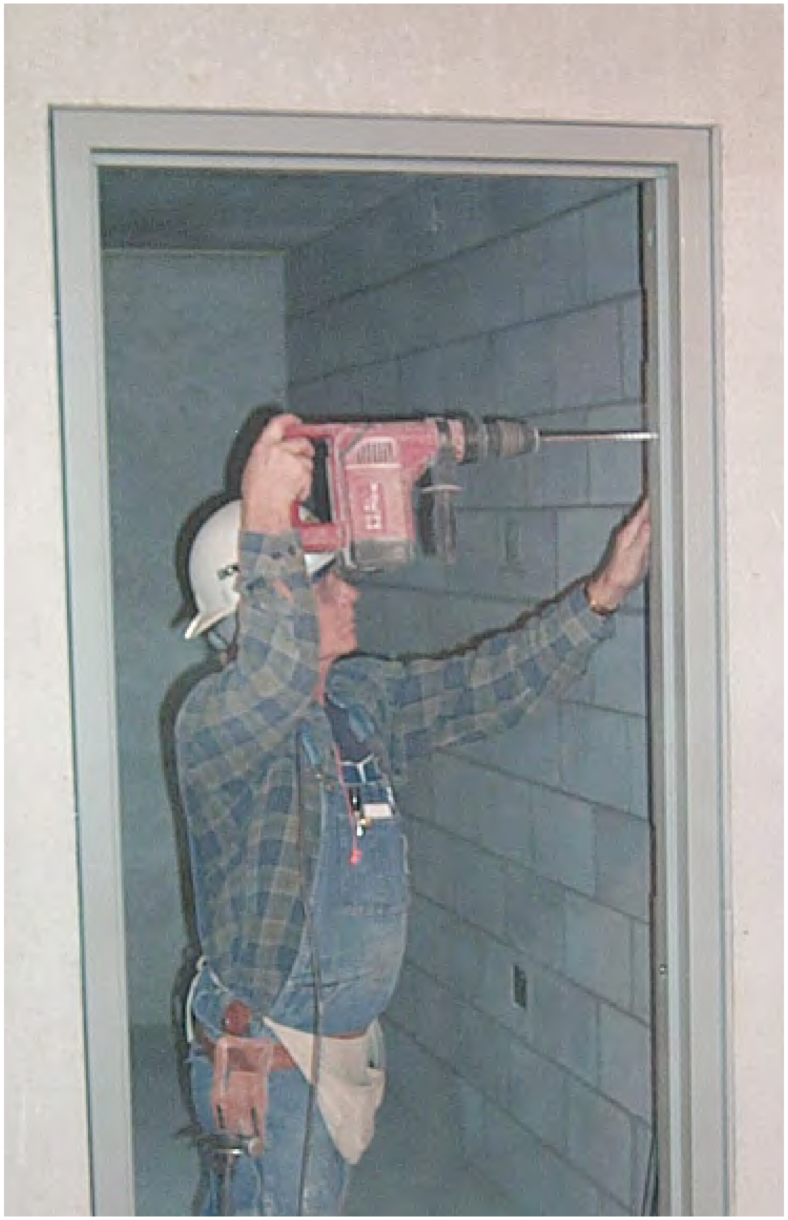


Door Installation: The Little Steps

Ready to Install

Laying out

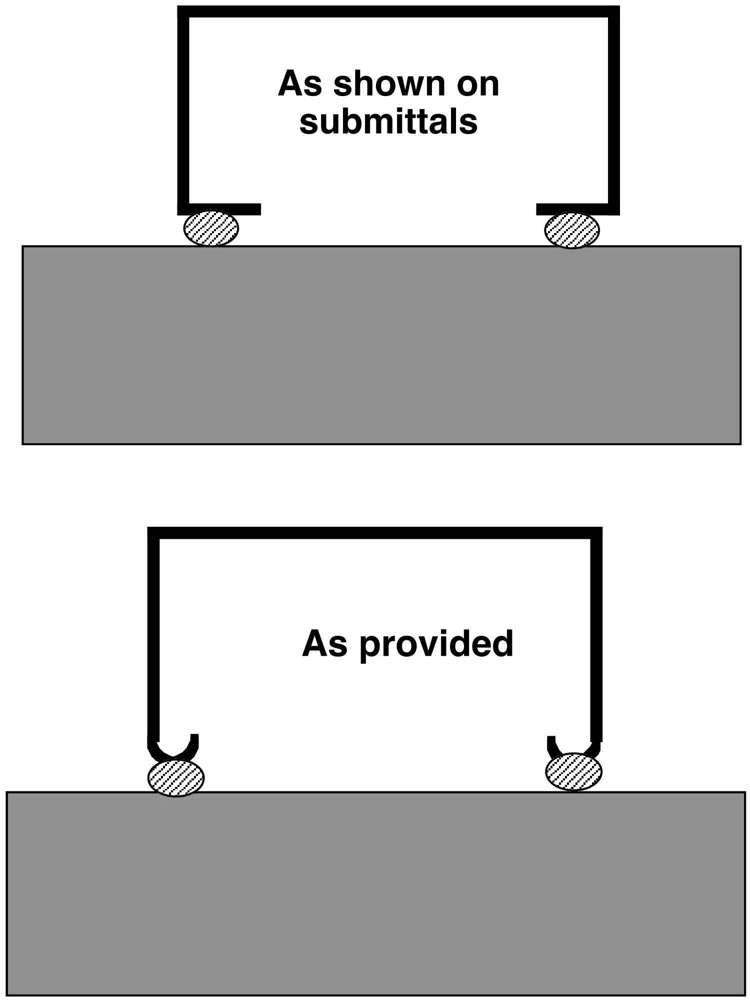
Drilling



Shimming

Trimming the Shim

Backer Rods

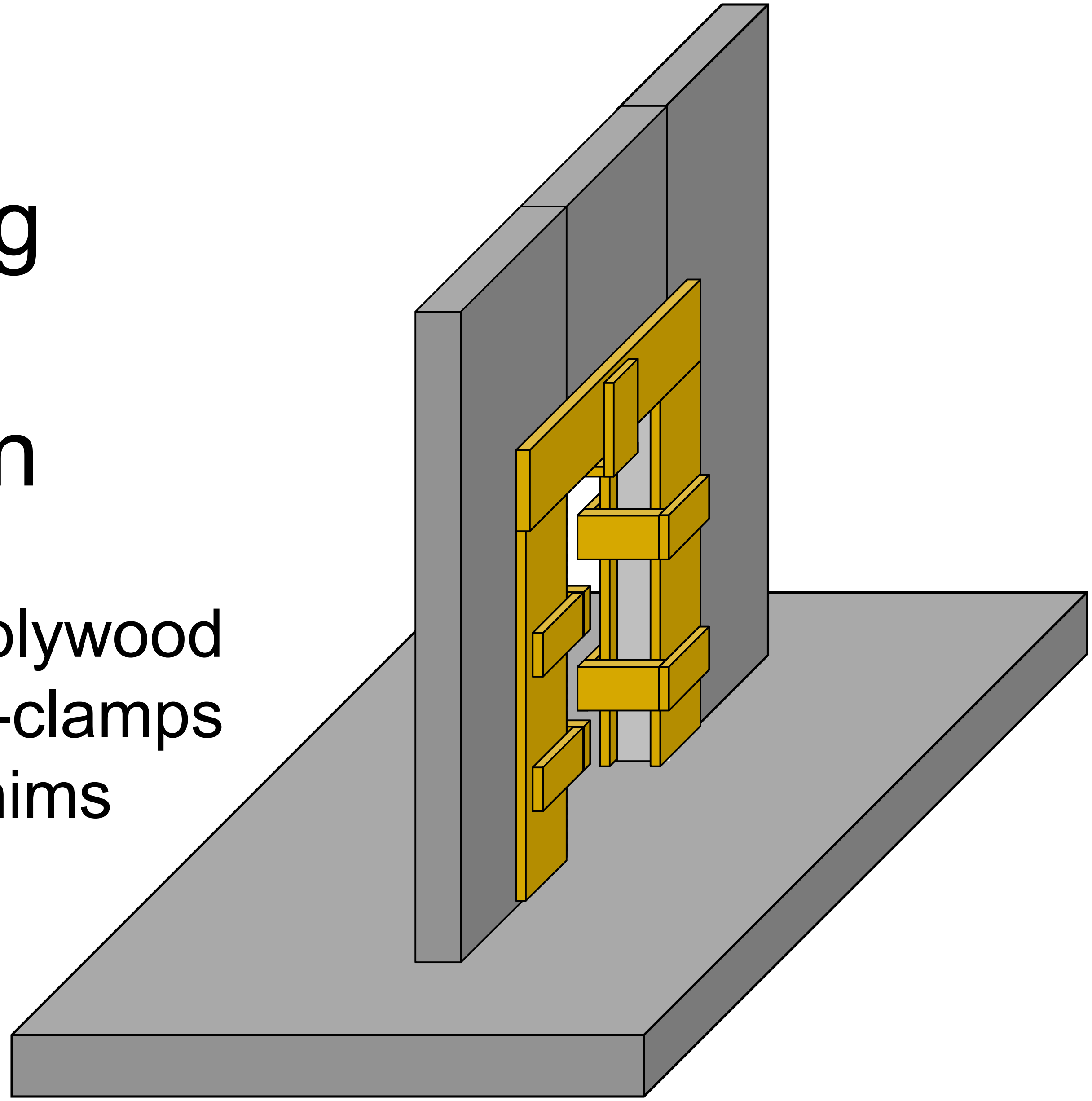


Caulking Outside

Feathering Caulk

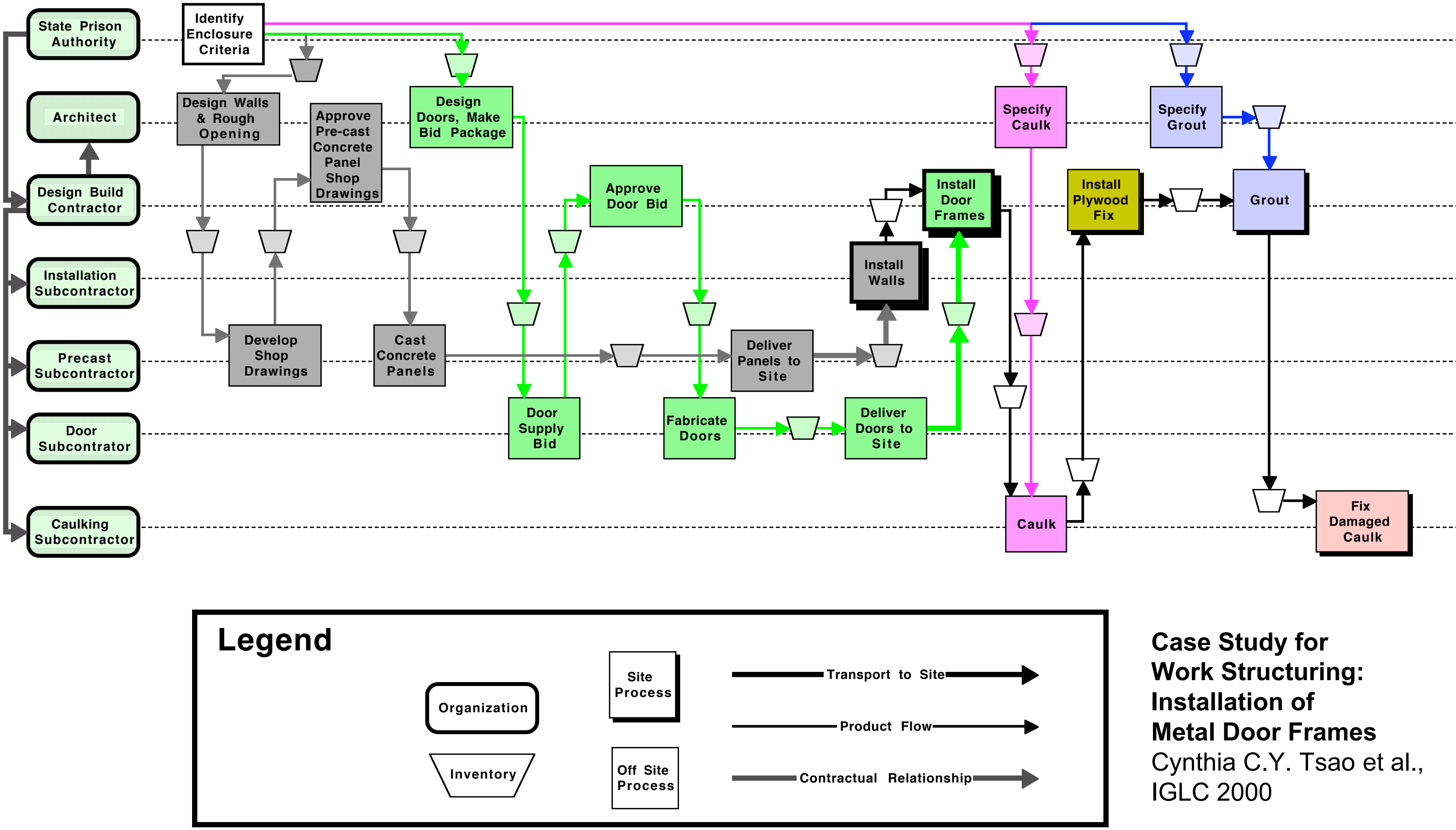
Keeping the Grout In

- U-shaped plywood
- Plywood C-clamps
- Wooden shims



Door Inventory

Supply and Contractual Relationships



Case Study for Work Structuring: Installation of Metal Door Frames
Cynthia C.Y. Tsao et al., IGLC 2000

Discussion

- Why did they do it the way they did?
  (What "organizing principle" was applied?)
- How would you do it if you were doing it right? Identify the new "organizing principle".

Work Structuring as Design

- **Lean Work Structuring IS PROCESS DESIGN**
- **As in product design, options must be considered and these may reveal different dimensions of the problem.**
- **Expect iteration between consideration of the design of “What” is to be built, and “How” to build it.**
- **Since work structuring recurs, early decisions as to “What” must fully consider “How” or leave adequate room for later decisions.**
- **“Change” often is the result of over-specifying “What” while not considering “How.”**

Lean Work Structuring

- **In what chunks will work be assigned to specialists?**
- **How will work chunks be sequenced?**
- **How will work be released from one production unit to the next?**
- **Will consecutive production units execute work in a continuous flow process or will their work be de-coupled?**
- **Where will de-coupling buffers be needed and how should they be sized?**
- **How will tolerances be managed?**
- **When will different chunks of work be done?**

Work Structuring is Not WBS

- **The objective of WBS is to assure that all scopes of work are assigned and that none overlap.**
- **Lean Work Structuring (LWS) strives for the best approximation of the lean ideal.**
- **LWS "chunks" work so that it**
  - **1) can be produced rapidly and for a low cost,**
  - **2) supports optimizing at the project level, and**
  - **3) delivers value to the customer and producer.**

What are your takeaways?

What questions have been provoked?

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- The Physics of Production-Work Flow
  - The Parade of Trades Simulation
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  - Workflow loop
- Production System Control using the Last Planner® System
  - Pull scheduling
  - Lookahead planning
  - Reliable promising
  - Learning
- More about Lean Project Delivery (if time available)
- Implementation/Organization Structuring
- Research directions
- Wrap up

Seminar Objectives

- Understand the theoretical basis of the Lean Project Delivery System.
- Understand its language, essential features, principles, tools and techniques.
- Make clear the primary differences between the Lean Project Delivery System and current practice.
- Encourage you to take action.

Introduction to Lean Construction: Work Structuring and Production Control

Presented by the

Lean Construction Institute

Glenn Ballard & Greg Howell

Presented at

UNIVERSITY OF Cincinnati

Cincinnati, Ohio

April 20-21, 2006

www.leanconstruction.org

Agenda

- Start up
- Work Structuring/Production System Design
  - Airplane Simulation
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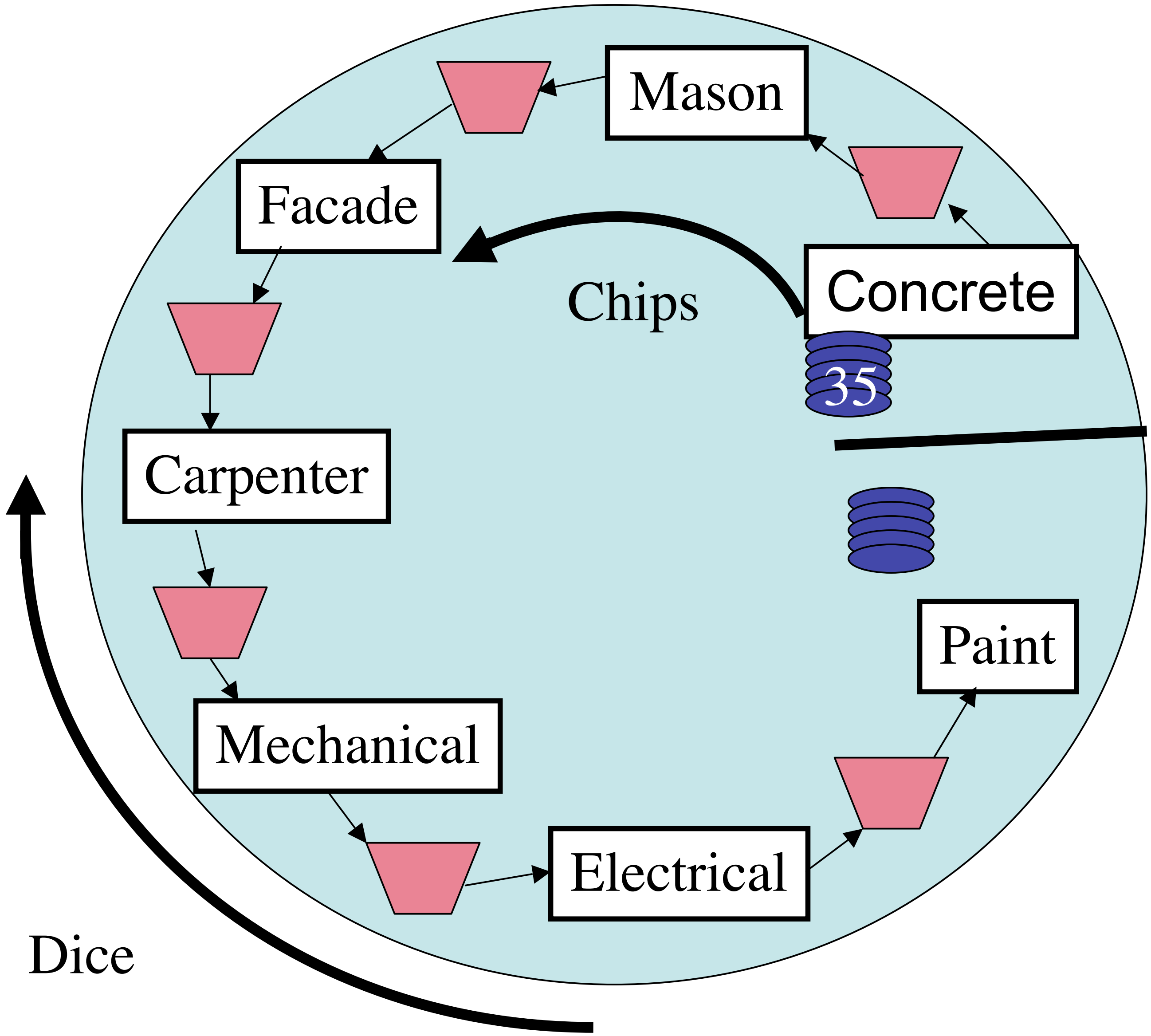

Mason
Facade
Chips
Concrete
35
Carpenter
Paint
Mechanical
Electrical
Dice

Week 1

Concrete

	Capacity (Rolled)	Passed	Lost Capacity	Remaining Incoming Inventory (Backlog)
Week	Number on Dice	Moved Chips	Capacity-Passed=	Available-Used = Remaining
1	3	3	0	35
2				
3				

Week 2

Mason

3

	Capacity (Rolled)	Passed	Lost Capacity	Remaining Incoming Inventory (Backlog)
Week	Number on Dice	Moved Chips	Capacity-Passed=	Available-Used = Remaining
2	2	2	0	1
3				

Concrete

	Capacity (Rolled)	Passed	Lost Capacity	Remaining Incoming Inventory (Backlog)
Week	Number on Dice	Moved Chips	Capacity-Passed=	Available-Used = Remaining
1	3	3	0	32
2	2	2	0	30
3				

Facade

2

	Capacity (Rolled)	Passed	Lost Capacity	Remaining Incoming Inventory (Backlog)
Week	Number on Dice	Moved Chips	Capacity-Passed=	Available-Used = Remaining
3	5	2	3	0

Mason

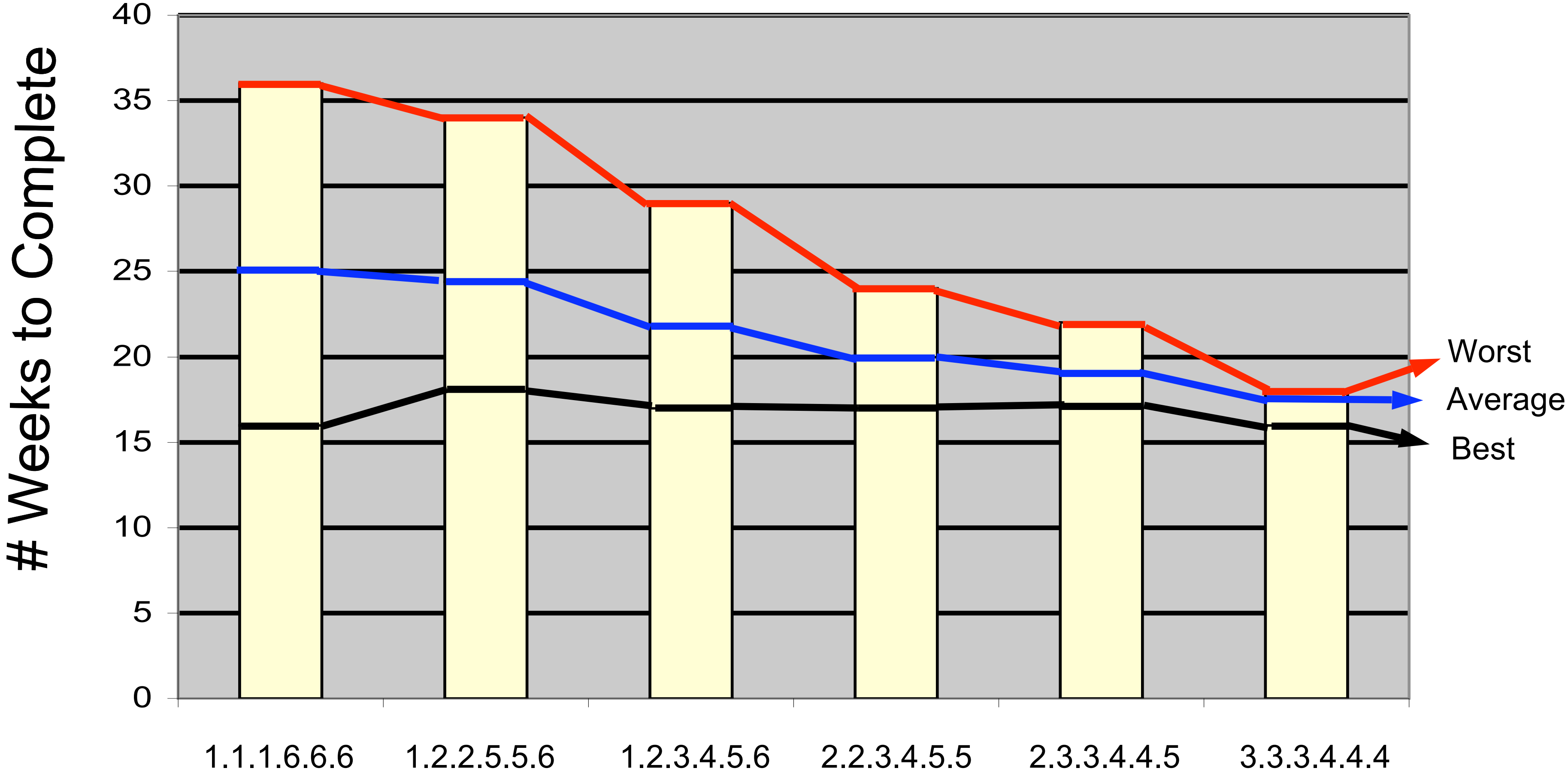
3

	Capacity (Rolled)	Passed	Lost Capacity	Remaining Incoming Inventory (Backlog)
Week	Number on Dice	Moved Chips	Capacity-Passed=	Available-Used = Remaining
2	2	2	0	1
3	5	3	2	0

Concrete

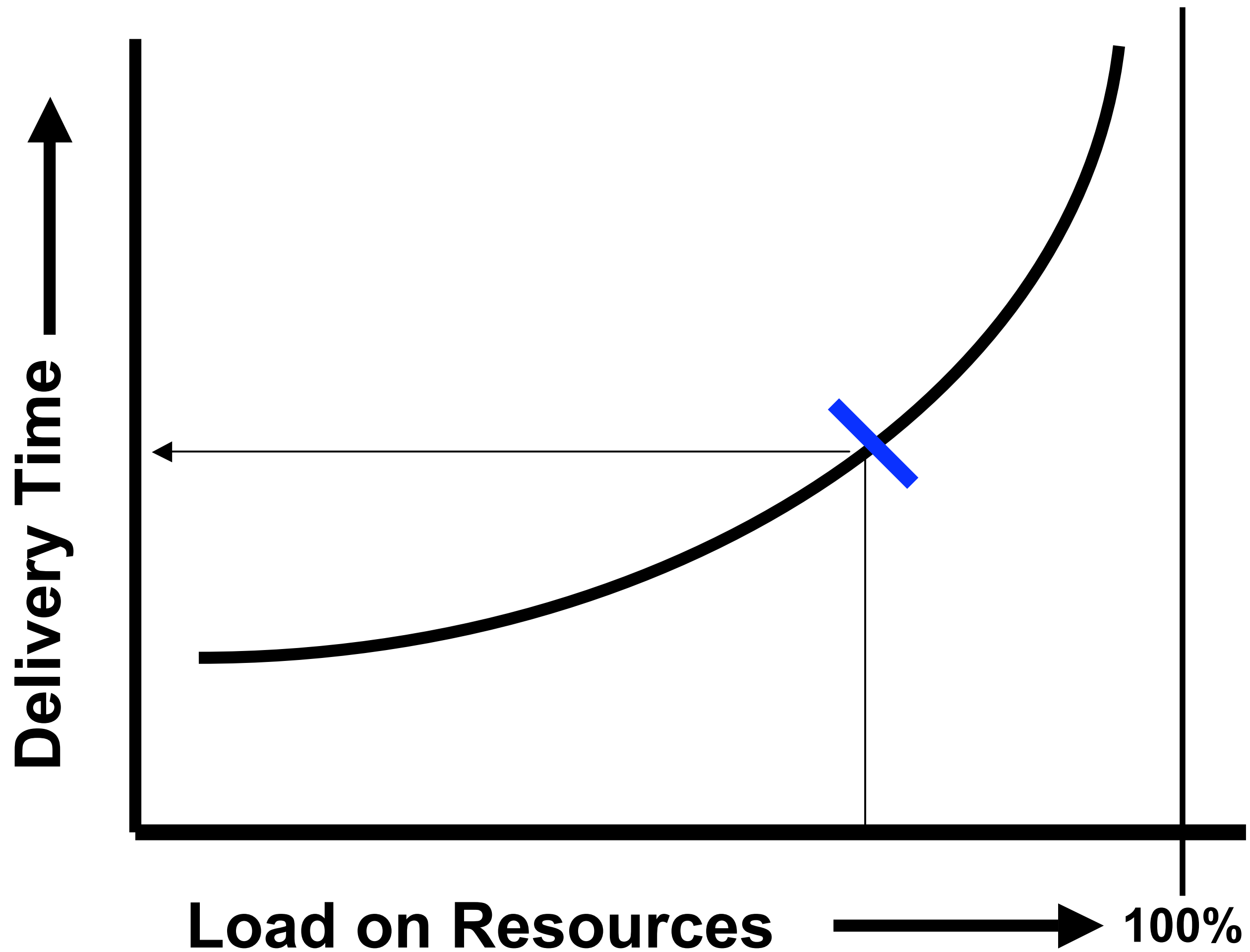
	Capacity (Rolled)	Passed	Lost Capacity	Remaining Incoming Inventory (Backlog)
Week	Number on Dice	Moved Chips	Capacity-Passed=	Available-Used = Remaining
1	3	3	0	32
2	2	2	0	30
3	1	1	0	29

RESULTS



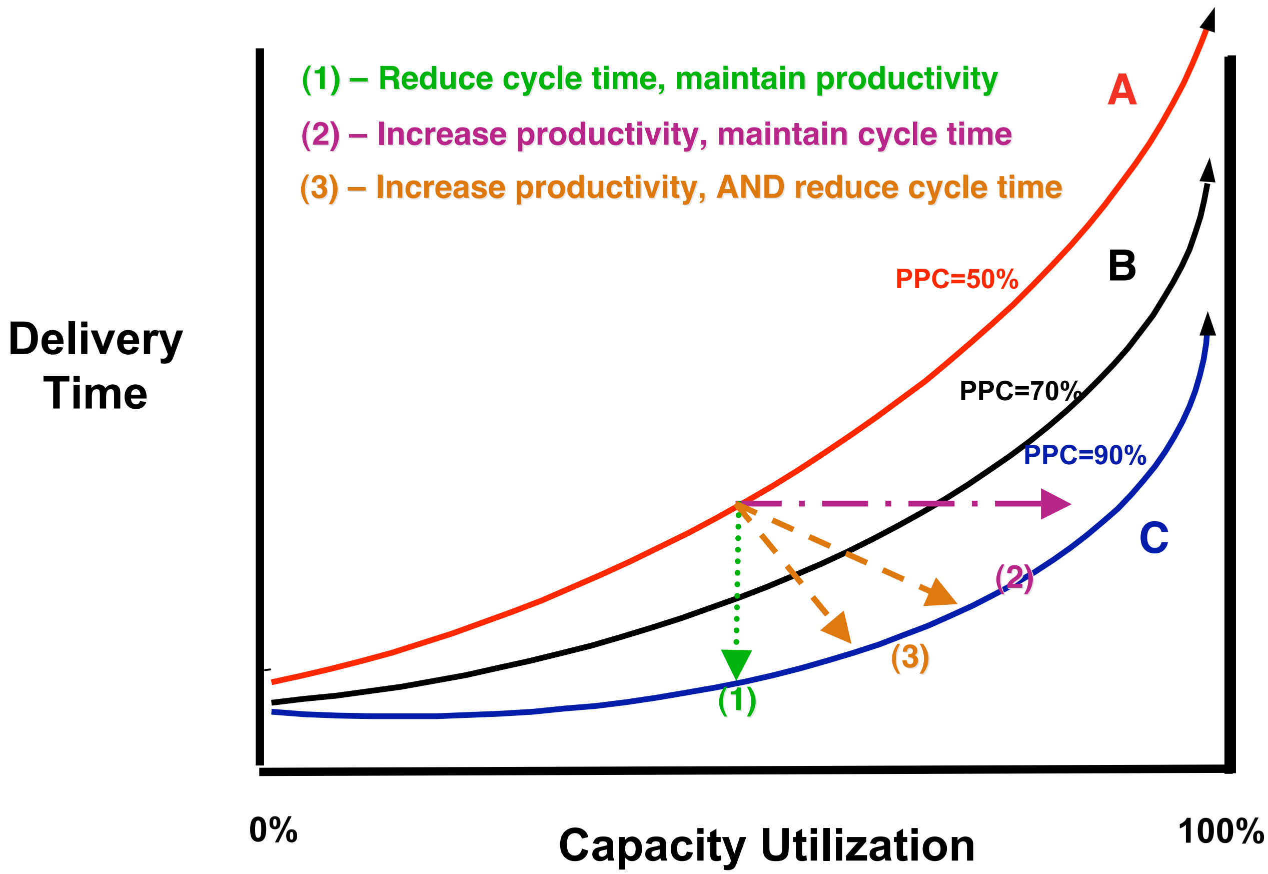
Average Loss	115.8	97.6	75.3	51.2	37	17.3

Physics of Production



Capacity Utilization (one factor in Productivity)

Time Cost Revisited



Key Points

- Reducing workflow variability
  - Improves total system performance
  - Makes project outcomes more predictable
  - Simplifies coordination
  - Reveals new opportunities for improvement
- Point speed and productivity don't matter – throughput does.
- Strategy: Reduce variation then go for speed to increase throughput.

Question for Discussion

What would be the specific advantages of improved work flow reliability on your projects?

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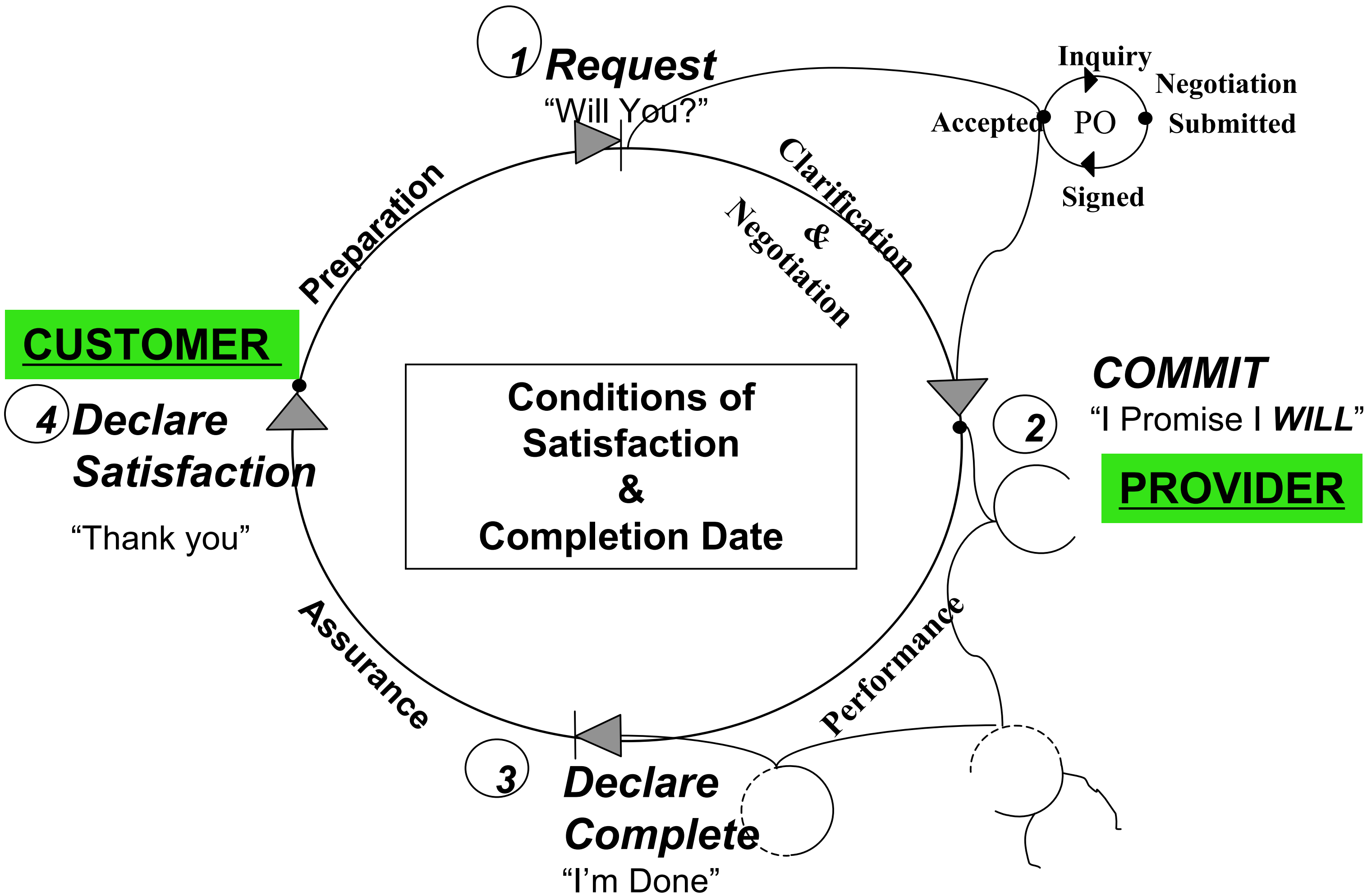
Planning ***IS*** Conversation

- Always has been.
- The key to coordinate actions if…
- You talk about the right things, and
- Create coherent commitments linking client value to the work of specialists, and coordinates that to their action.

The “Physics” of Coordination



Reliable Promises - 5 test questions

1. **Am I competent to perform or do I have access to competence?**
2. **Have I estimated the amount of time (hands-on) required for this work?**
3. **Do I have the capacity available & allocated?**
4. **Am I having a private unspoken conversation in conflict with promise?**
5. **Will I be responsible?**

Problems with Current Practice

- Activity Focus ignores value creation and the flow of work.
  - Collaboration in design is limited
  - Fails to produce predictable work flow
- Command and Control planning cannot coordinate the arrival of the wherewithal or work of specialists.
  - Opportunities for trading ponies for horses are lost
  - Push systems are commitment free zones.
- Control begins with tracking cost and schedule.
  - Efforts to improve productivity leads to Unreliable Work Flow further reducing project performance.
  - Protecting activities leads to adversarial relations.

Project Based Production

- Structure work to maximize value and throughput and control work flow while minimizing idle inventory and resources.
- Make work ready and release it at the right time and in the right sequence.
- Plan and coordinate action through reliable promising.
- Learn from failures and take advantage of the opportunities it creates.
- Maximize performance at the project level, continue to learn.

Agenda

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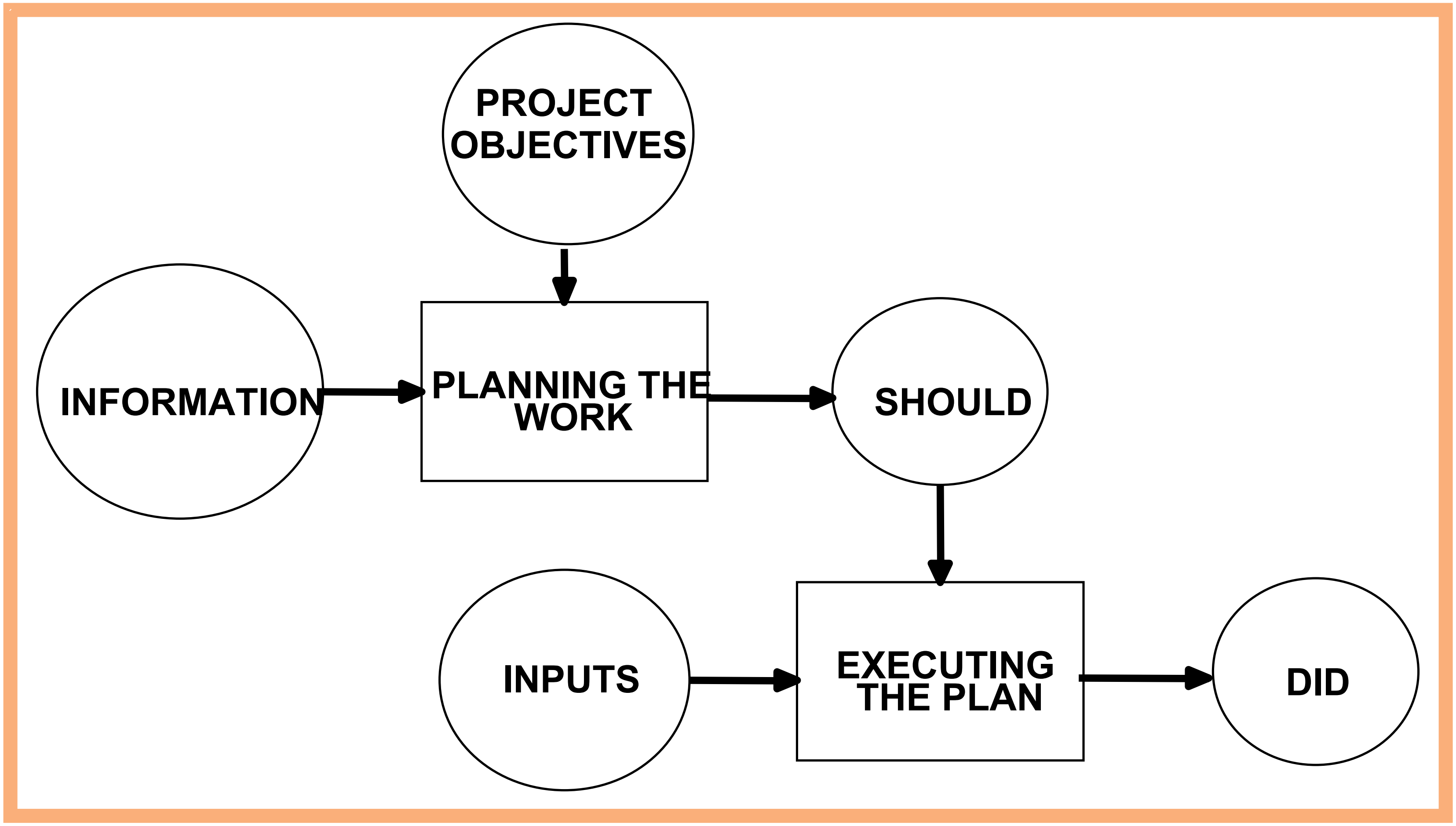
A Traditional (Push) Planning System



Construction Weekly Work Plan

1 WEEK PLAN

PROJECT: Pilot | **FOREMAN: PHILLIP**

ACTIVITY | **DATE: 9/20/96**

ACTIVITY	Est	Act	Mon	Tu	Wed	Thurs	Fri	Sat	Sun	PPC	REASON FOR VARIANCES
Gas/F.O. hangers O/H "K" (48 hangers)			xxxx Sylvano, Modesto, Terry	xxxx						No	Owner stopped work (changing elevations)
Gas/F.O. risers to O/H "K" (3 risers)					xxxx Sylvano, Mdesto, Terry	xxxx	xxxx	xxxx		No	Same as above-worked on backlog & boiler blowdown
36" cond water "K" 42' 2-45 deg 1-90 deg			xxxx Charlie, Rick, Ben	xxxx	xxxx					Yes	
Chiller risers (2 chillers wk.)						xxxx Charlie, Rick, Ben	xxxx	xxxx		No	Matl from shop rcvd late Thurs. Grooved couplings shipped late.
Hang H/W O/H "J" (240'-14")			xxxx Mark M., Mike	xxxx	xxxx	xxxx	xxxx	xxxx		Yes	
Cooling Tower 10" tie-ins (steel) (2 towers per day)			xxxx Steve, Chris, Mark W.	xxxx	xxxx	xxxx	xxxx	xxxx		Yes	
Weld out CHW pump headers "J" mezz. (18)			xxxx Luke	xxxx	xxxx	xxxx	xxxx	xxxx		Yes	
Weld out cooling towers (12 towers)			xxxx Jeff	xxxx	xxxx	xxxx	xxxx	xxxx		No	Eye injury. Lost 2 days welding time
F.R.P. tie-in to E.T. (9 towers) 50%			xxxx Firt, Packy, Tom	xxxx	xxxx	xxxx	xxxx	xxxx		Yes	
WORKABLE BACKLOG Boiler blowdown-gas vents -rupture disks											

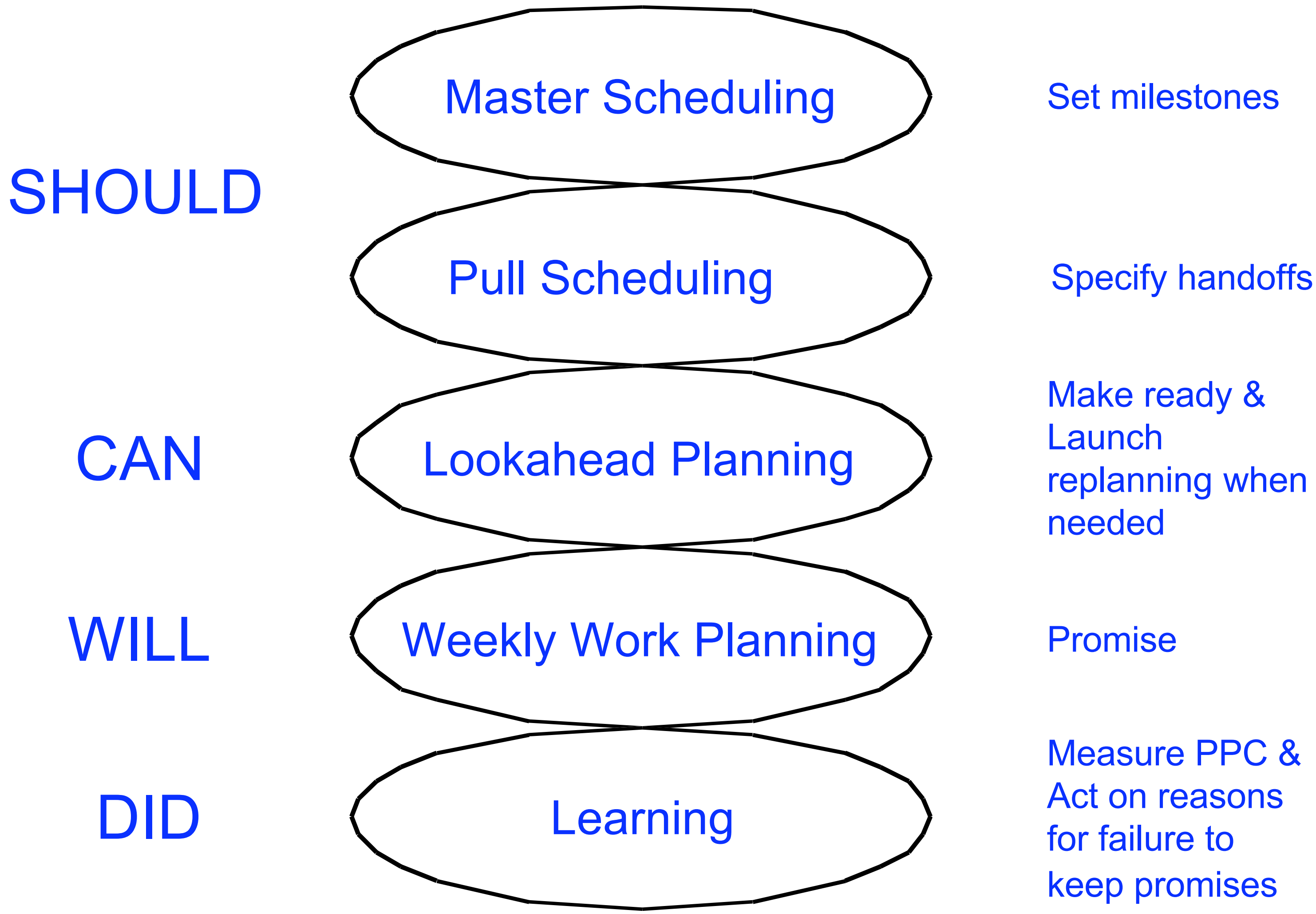
Traditional Management Increases Variability: Plan Reliability Data

Contractor 1	33 %
Contractor 2	52 %
Contractor 3	61 %
Contractor 4	70 %
Contractor 5	64 %
Contractor 6	57 %
Contractor 7	45 %
Average	54 %

Helmuth von Moltke
Head of the Prussian & German Staff 1858-1888

- **No plan of operations extends with certainty beyond the first encounter with the enemy's main strength. Only the layman sees in the course of a campaign a consistent execution of preconceived and highly detailed original concept pursued consistently to the end.**
- **Certainly the commander and chief will keep his great objective continuously in mind, undisturbed by the vicissitudes of events. But the path on which he hopes to reach it can never be firmly established in advance.**
- **Throughout the campaign he must make a series of decisions on the basis of conditions that cannot be foreseen. The successive acts of war are thus not premeditated designs, but on the contrary are spontaneous acts guided by military measures.**
- **Everything depends on penetrating the uncertainty of veiled situations to evaluate the facts, to clarify the unknown, to make decisions rapidly, and then to carry them out with strength and constancy.**

The Last Planner® System of Production Control

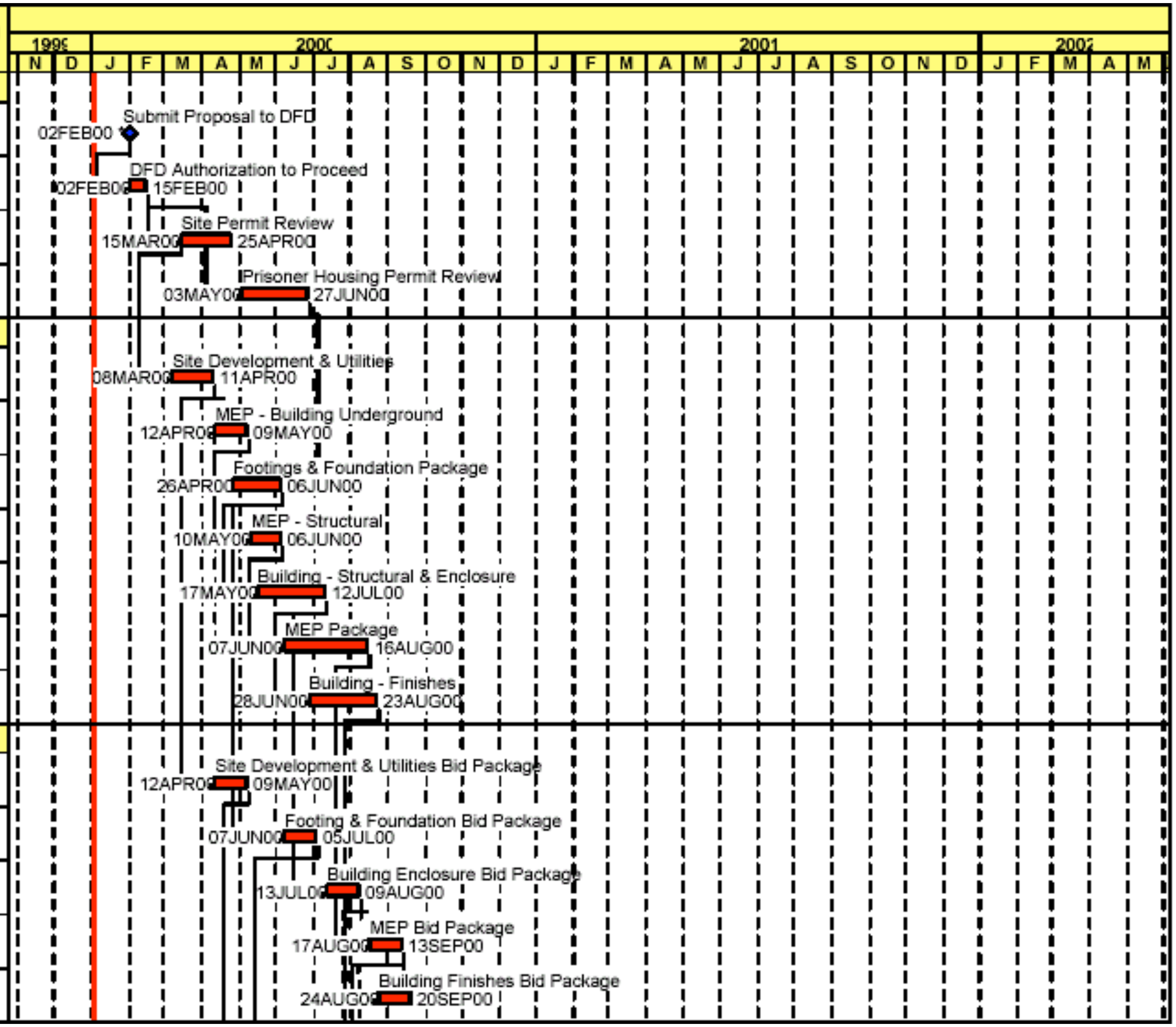


Who is the Last Planner®?

- The person or team that gives assignments (makes requests for commitments) to production units such as design squads or construction crews.

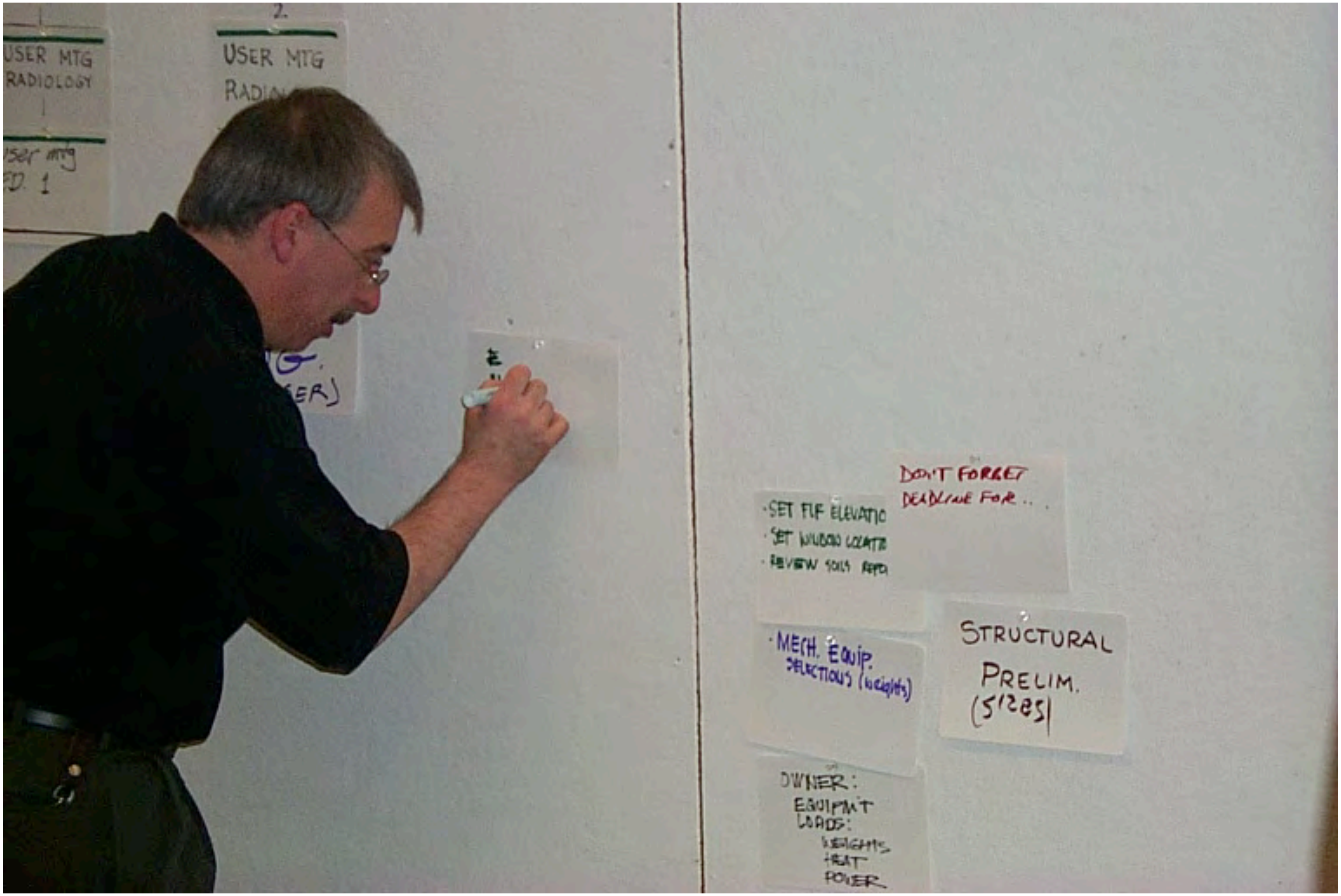
Master Schedule-1

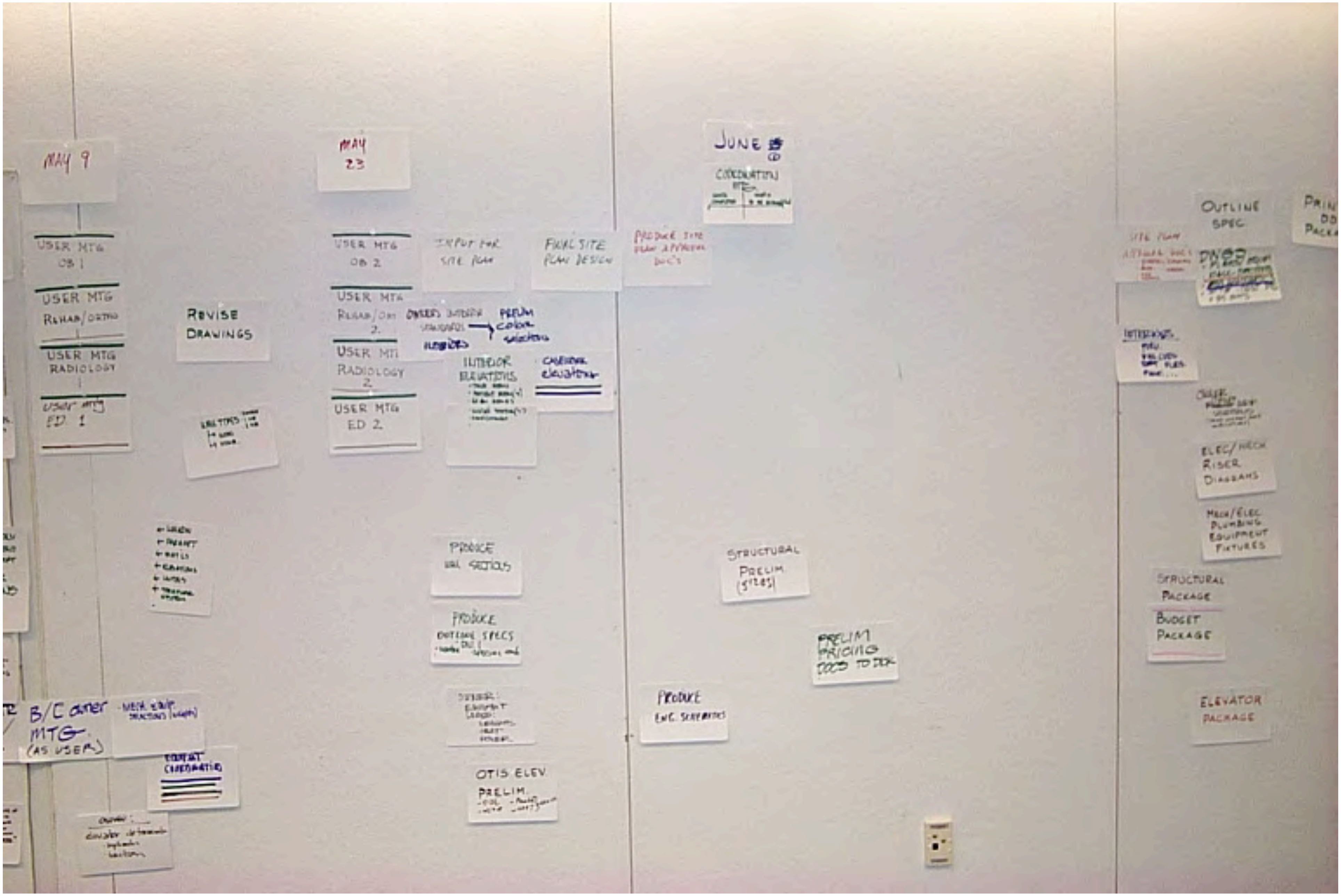
Act ID	Description	Orig Dur
Approval Process		
1000	Submit Proposal to DFD	0
1010	DFD Authorization to Proceed	10d
1030	Site Permit Review	30d
1050	Prisoner Housing Permit Review	40d
Design Phase		
1080	Site Development & Utilities	25d
1105	MEP - Building Underground	20d
1085	Footings & Foundation Package	30d
1115	MEP - Structural	20d
1090	Building - Structural & Enclosure	40d
1095	MEP Package	50d
1098	Building - Finishes	40d
Bid Packages		
1240	Site Development & Utilities Bid Package	20d
1250	Footing & Foundation Bid Package	20d
1270	Building Enclosure Bid Package	20d
1260	MEP Bid Package	20d
1470	Building Finishes Bid Package	20d



Functions of Master Schedules

- Demonstrate the feasibility of completing the work within the available time.
- Develop and display execution strategies.
- Determine when long lead items will be needed.
- Identify milestones important to client or stakeholders.


USER MTG
RADIOLOGY
USER MTG
DON'T FORGET
DEADLINE FOR...
·SET FLF ELEVATIO
·MECH. EQUIP.
SELECTIONS (weights)
STRUCTURAL
PRELIM.
(5/28S)
OWNER:
EQUIPM'T
LOADS:
WEIGHTS
HEAT
POWER


MAY 9
MAY 23
JUNE
USER MTG OB 1
USER MTG REHAB/ORTHO
USER MTG RADIOLOGY
USER MTG ED 1
REVISE DRAWINGS
USER MTG OB 2
INPUT FOR SITE PLAN
FINAL SITE PLAN DESIGN
PRODUCE SITE PLAN APPROVAL DOCS
USER MTG RADIOLOGY 2
USER MTG ED 2
INTERIOR ELEVATIONS
PRELIM COLOR SELECTIONS
OUTLINE SPEC
ELEC/MECH RISER DIAGRAMS
MECH/ELEC PLUMBING EQUIPMENT FIXTURES
STRUCTURAL PACKAGE
BUDGET PACKAGE
ELEVATOR PACKAGE
STRUCTURAL PRELIM (SIZES)
PRELIM PRICING DOCS TO DCK
PRODUCE ENG. SCHEMATICS
OTIS ELEV PRELIM
PRODUCE OUTLINE SPECS
B/C OWNER MTG (AS USER)


Wall Close in

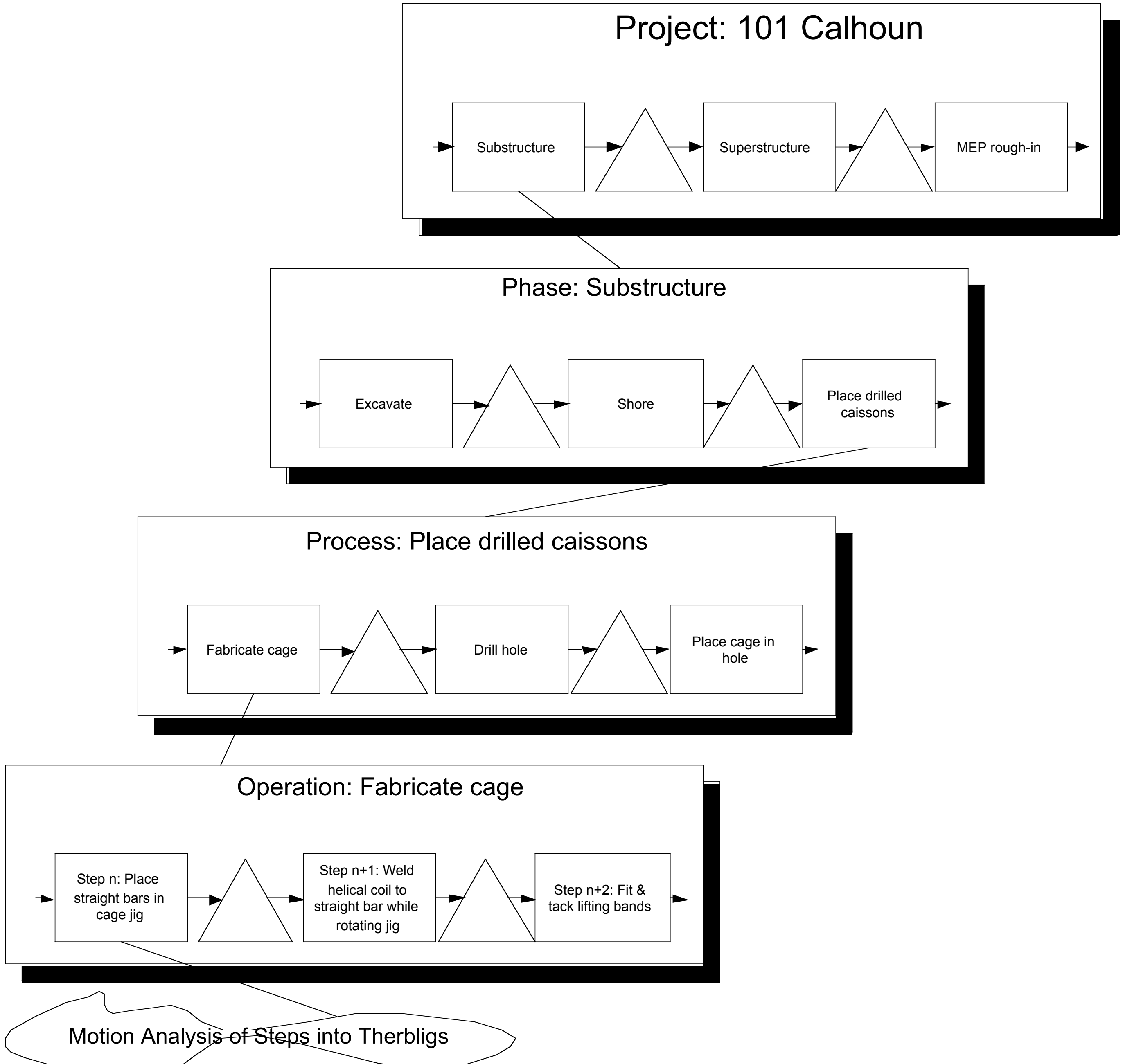
Linking Scheduling & Production Control

Proposed schema for work structures:

- ***Projects*** consist of phases.
- ***Phases*** (site prep., substructure, superstructure,….) consist of processes.
- ***Processes*** (w/in substructure: layout, excavate, shore, place drilled caissons,….) consist of operations.
- ***Operations*** (w/in place drilled caissons: fabricate cage, drill hole, place cage, pour concrete) consist of steps.
- ***Steps*** (w/in fabricate cage: acquire materials, place straight bar in jig, weld coiled bar helically around cylinder, fit & tack lifting bands, weld out lifting bands) consist of motions.

*Today's **assignment** for X: Perform welding steps in the operation Fabricate Cage. Fabricate cages 101, 102 and 103 in that order.*

The goal of control is the handoffs between work groups performing different processes within phases.



Project: 101 Calhoun
Substructure
Superstructure
MEP rough-in
Phase: Substructure
Excavate
Shore
Place drilled caissons
Process: Place drilled caissons
Fabricate cage
Drill hole
Place cage in hole
Operation: Fabricate cage
Step n: Place straight bars in cage jig
Step n+1: Weld helical coil to straight bar while rotating jig
Step n+2: Fit & tack lifting bands
Motion Analysis of Steps into Therbligs

Pull Scheduling: Designing the Network of Commitments

- Produce the best possible plan by involving all with relevant expertise and by planning near action.
- Assure that everyone in a phase understands and supports the plan by developing the schedule as a team.
- Assure the selection of value adding tasks that release other work by working backwards from the target completion date to produce a pull schedule.
- Publicly determine the amount of time available for ‘contingency’ and decide as a group how to spend it.

The Last Planner® System of Production Control

MILESTONE = RTT1B

LOOK AHEAD PLAN

GROUP	MHM
PROGRAM	Delta
PROJECT	Women's Center
PROJECT NUMBER	02074639
RESPONSIBLE INDIVIDUAL	Bill Ortiz

STATUS	ACTIVITY	RESPONSIBLE PARTY	WEEK START 16-Aug	23-Aug-04 23-Aug	30-Aug	6-Sep	13-Sep	20-Sep	27-Sep	4-Oct	11-Oct	18-Oct	RFI OR CONSTRAINT #
	Area 1BME												
	Frame	**Brian**											
	In Wall Inspection	**Bill S.**											
	Rock Walls	**Brian**	**R**										
	Screw Inspection	**Bill S.**	**X**										
	Taping	**Brian**	**X**	**M**									
	Painting	**DC Vient**		**M**									
	Mechanical Pads	**ICC**											
	Set Mechanical Equipment	**Richard**		**X**	**X**								
	Measure/Procure/Install Boiler Flues	**Richard**			**X**	**X**	**X**						
	Set Electrical Equipment	**Dave**			**X**	**X**	**X**						**294**
	Registers	**Richard**						**X**					
	Lights	**Dave**						**X**					
	Area 1B1 -Core Walls												
	Frame	**Brian**	**X**										**259**
	In Wall Plumbing	**John**											
	In Wall Medical Gas	**John**	**R**										**256**
	In Wall Electrical	**Dave**	**X**	**X**									**203, 229, 270**
	In Wall Controls	**DDC**											
	Backing	**Brian**											
	Rock One Side	**Brian**	**X**	**X**									
	Area 1B2 Walls												
	Framing	**Brian**	**X**										
	In Wall Electrical	**Dave**	**X**	**X**									**203, 229, 245**
	In Wall Controls	**DDC**											
	Backing	**Brian**	**X**										
	Rock One Side	**Brian**	**X**	**X**									

LOOKAHEAD SCHEDULE

BOLDT BUILDS
OSCAR J. BOLDT CONSTRUCTION COMPANY USA
Project: Same Day Sugery
Planner: Dena Deibert

Six Week Lookahead / Constraints Analysis

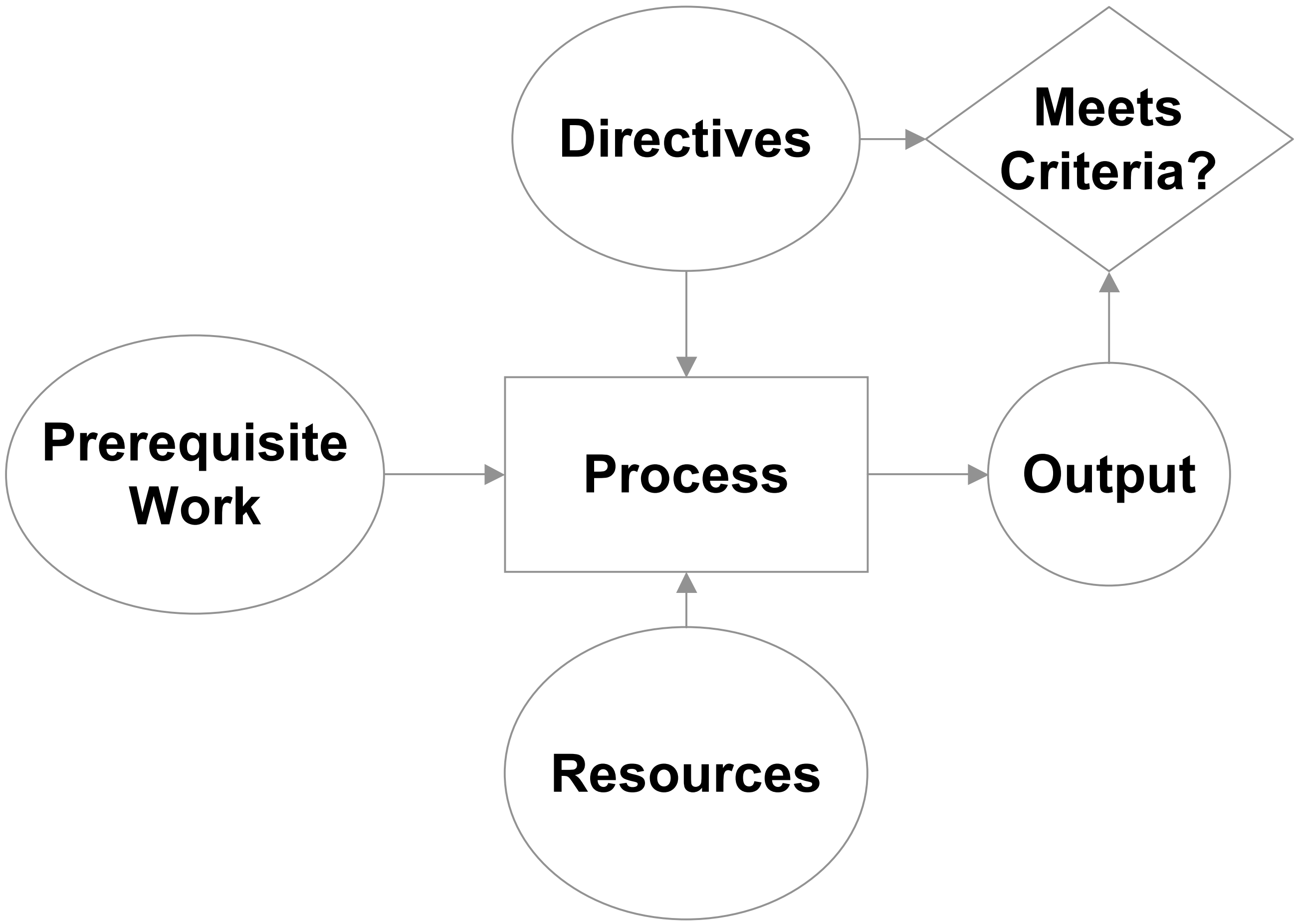
Week of 10-23-00

Week	Repeat	Activity	Responsible Party	10/24/04 MTWRFS	10/31/04 MTWRFS	11/7/04 MTWRFS	11/14/04 MTWRFS	11/21/04 MTWRFS	11/28/04 MTWRFS	Contract / C.O.'s	Safety	Space Planning	Budgeting	Engineering	Submittals	RFI's	Materials	Labor	Equipment	Prereq Work	Space	Comments / Other
1		Build mock-up of room 11	Boldt	x x x x x	x x x												x					Millwork & mirror
1	✓	Microscope vibration study	SLMC/ STS	x x x x x																		CD's will be issued prior to this info; Isolation system will come as addendum
1		Bid & award bid pack 3	Boldt	x x x x x																		Review with Brad
1		Submit-review-approve roofing shopdrwng	Langer	x x x x x	x x x x x										x							Additional submittals required
1		Release updated construction documents	ARC	x x x x x																		Coordinate with Ring & Du
1		Demolition	Boldt	x x x x x	x x x x x	x x x x x	x x x x x	x x x x x	x x x x													
1		Pour roof	Boldt	x																x		
1		Expedite stone production	BDI	x x x x x	x x x x x	x x x x x	x x x x x	x x x x x	x x x x	x					x							Stone was ordered 10-19-00
1		Steel Shops: Curtainwall Support	Duwe	x x x x x	x x x x x															x		Klein Dickert will coordinate with Mike D
1		Roof detailing	Duwe	x x	x x x															x		
1		Phase 3 Millwork Shop Drwngs	Precision	x x x x x	x x x x x	x x x x x																
1		Fabricate louvers	Air Flow	x x x x x	x x x x x	x x x x x	x x x x x	x x x x x	x x x x						x							5-6 week lead time - Ordered 10-19-00
1	✓	Fabricate auto entrance doors	Besam	x x x x x	x x x x x																	Shipping 11-3; Besam header to Dickert
1	✓	Fabricate curtainwall	Klein Dickert	x x x x x	x x x x x	x x x x x	x x x x x								x		x					Waiting for framing materials-by October
2		Mock-up review	SLMC		x x	x x											x			x		Millwork; Mirror
2		Masonry Work	BDI		x x x	x x x x x	x x x x x	x x x x x	x x x x								x					Roger needs to confirm if brick is in
2		Penthouse framing & decking	Duwe		x x x	x x														x		Boldt to confirm placement of AHU's
2		Bid Pack 3 Submittals	TBD		x x x x x	x x x x x	x x x x x			x										x		Award contracts
2		Start work on patient rooms 3847 -49	TBD		x x x x x	x x x x x	x x x x x					x	x									Need to coordinate with Jan Keepers
		Workable Backlog																				
		Fabricate AHU's / ACCU	Trane																			Shipping: 11-13-00
		Med Gas Equip. Lead-Time	Squires																			Delivery: 11-6-00
		Demo shades at main entrance	TBD							x												
		Review room numbering	ARC/ Lukes																			

Functions of the Lookahead Process

- Shape work flow sequence and rate
- Match work flow and capacity
- Maintain a backlog of ready work
- Develop detailed plans for how work is to be done
  - Safety, environmental, quality issues

Mapping Language: Activity Definition Model



Constraints Analysis: Design

Project: Mega Bldg

Report Date: 3 Nov

C O N S T R A I N T S

Activity	**Respons-ible Party**	**Scheduled Duration**	**Directives**	**Pre-requisites**	**Resources**	**Comments**	**Ready?**
Design slab	Structural Engineer	15 Nov to 27 Nov	Code 98 Finish? Levelness?	Soils report	10 hours labor, 1 hr plotter		No
Get info. from client re floor finish & level	*Structural Engineer's gofer*	*3 Nov to 9 Nov*	OK	OK	OK		Yes
Get soils report from Civil	*Structural Engineer*	*By 9 Nov*	OK	OK	OK		Yes
Layout for tool install	Mechanical Engineer	15 Nov to 27 Nov	OK	Tool configurations from mfger	OK	May need to coord. w/ HVAC	No

How is the lookahead within Last Planner® different from traditional lookahead schedules?

- Traditional lookahead schedules are used to provide advance notice of activity starts in the service of sticking to a usually quite detailed master schedule.
- Traditional lookahead schedules do not:
  - Shape work flow sequence and rate
  - Match work flow and capacity
  - Maintain a backlog of ready work
  - Develop detailed plans for how work is to be done

Steps in the Lookahead Process

- <u>Explode</u> scheduled activities into assignment-level detail, using the Activity Definition Model and First Run Studies.
- <u>Screen</u> the constraints on each assigned task within the lookahead window.
- <u>Make</u> assigned tasks <u>ready</u> by removing constraints.
- <u>Balance</u> load and capacity by advancing/retarding scheduled work, increasing/decreasing capacity, or deciding how to invest excess capacity.
- <u>Adjust</u> phase or master schedules as needed.
- <u>Learn</u>: measure and improve performance.

First Run Studies

- An explicit, detailed plan for an operation developed prior to starting work. Includes consideration of safety, operation design including timing and location of activities, work flow, crew balance, tools, release of work downstream, etc.
- The plan is developed with those involved in doing the work, tested and improved.
- The actual process is recorded, analyzed to identify improvements.

PDCA Cycle

PLAN

1. Select work processes to study.
2. Before the first run of each process, assemble people with input or impact.
3. Chart the work process steps.
4. Brainstorm how to eliminate, reduce or overlap process steps.
5. Check process designs for safety; anticipate hazards and specify preventions.
6. From past experience, list probable errors and specify preventions. Plan for feedback and learning by identifying key variables to observe or data to collect.
7. Assign optimum labor, tool and equipment resources.

DO

8. Carry out the plan on the first run.

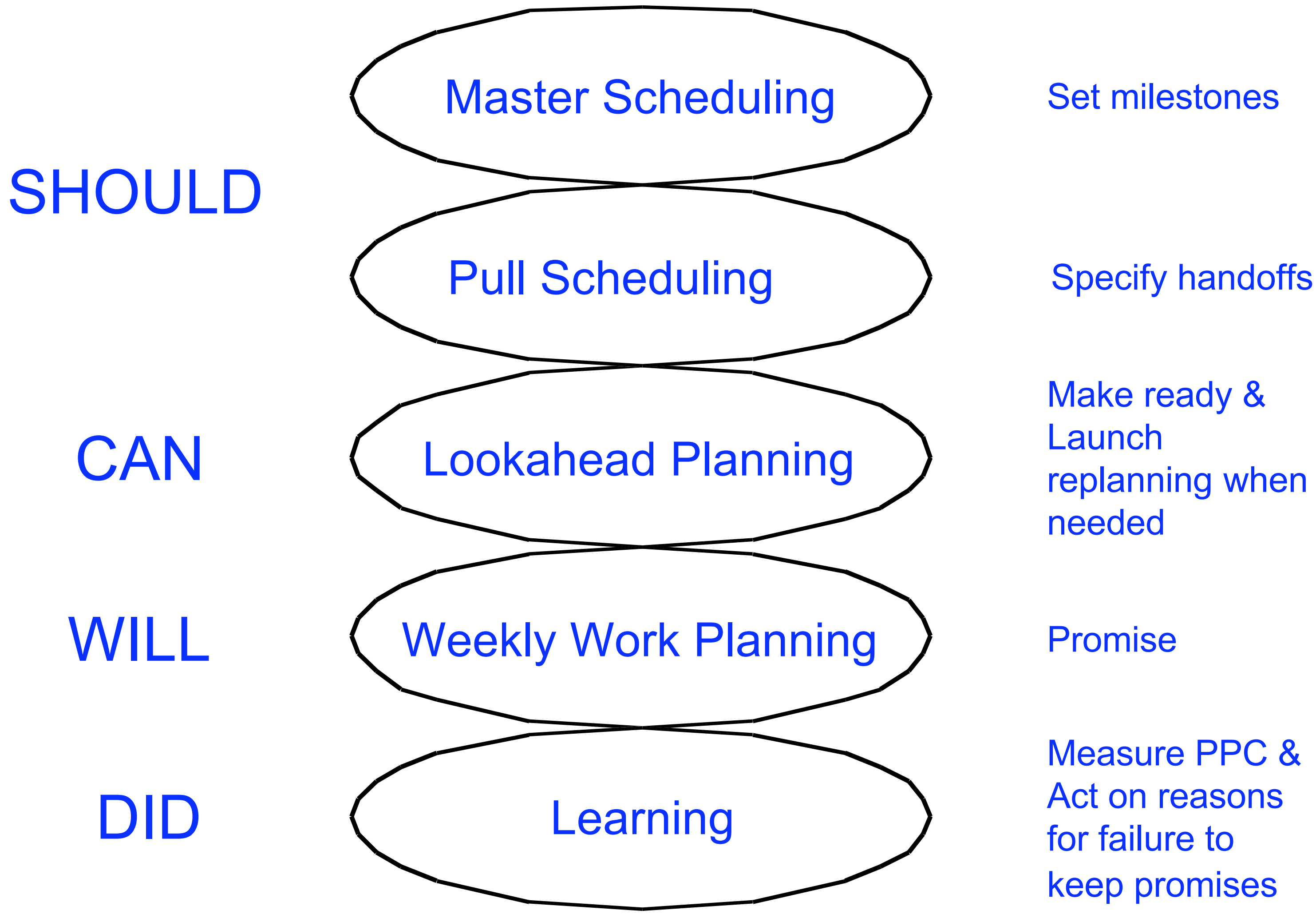
CHECK

9. Describe and measure what actually happens:
 - process steps, sequences and durations
 - interactions with other operations or crews
 - errors, omissions and rework
 - accidents, near misses and hazards
 - resources used (labor, tools, equipment, support crafts, etc)
 - outputs

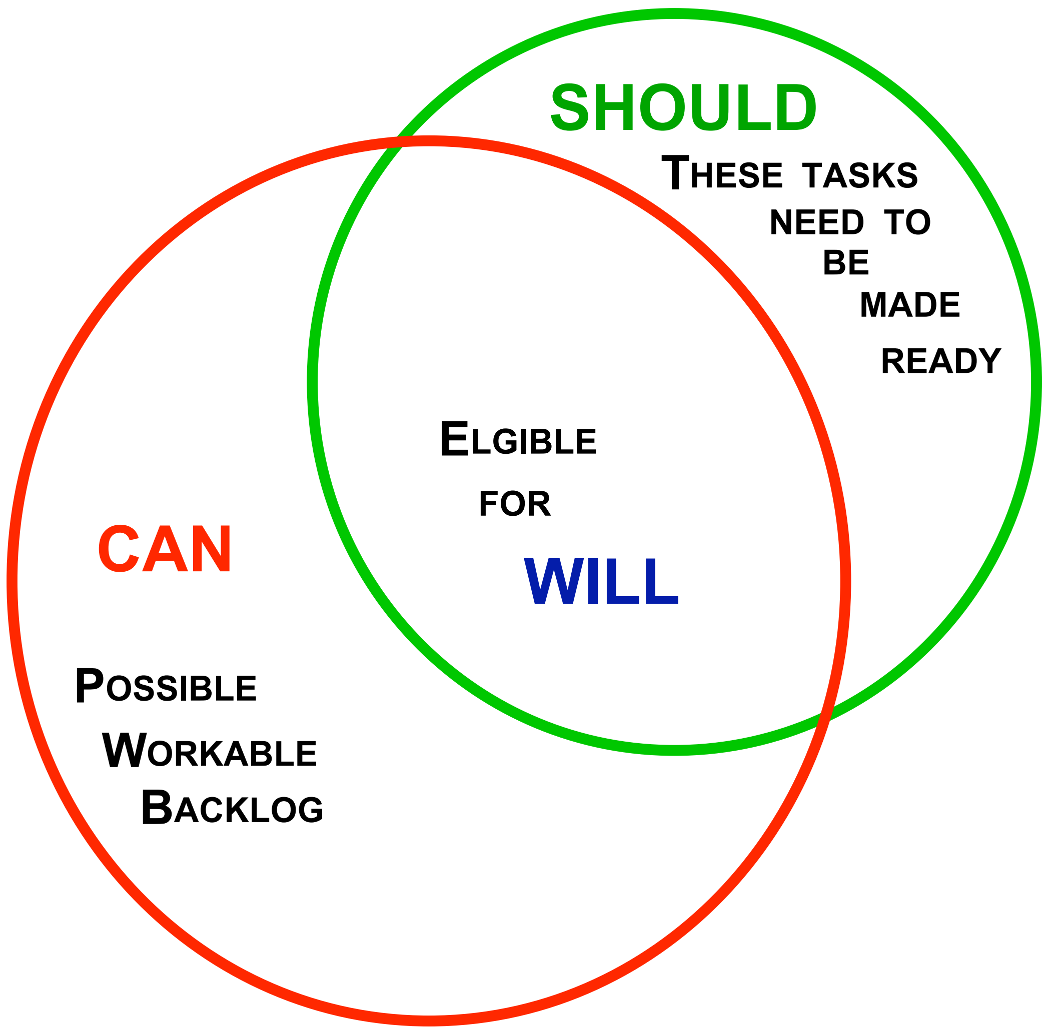
ACT

10. Reconvene the team, including those who actually did the work, review data and share ideas. Continue until opportunity for improvement is exhausted.

The Last Planner® System of Production Control



Forming the Commitment Plan



Weekly Plan & PPC

BOLDT BUILDS
OSCAR J. BOLDT CONSTRUCTION COMPANY USA

Project: Same Day Sugery
Planner: Dena Deibert

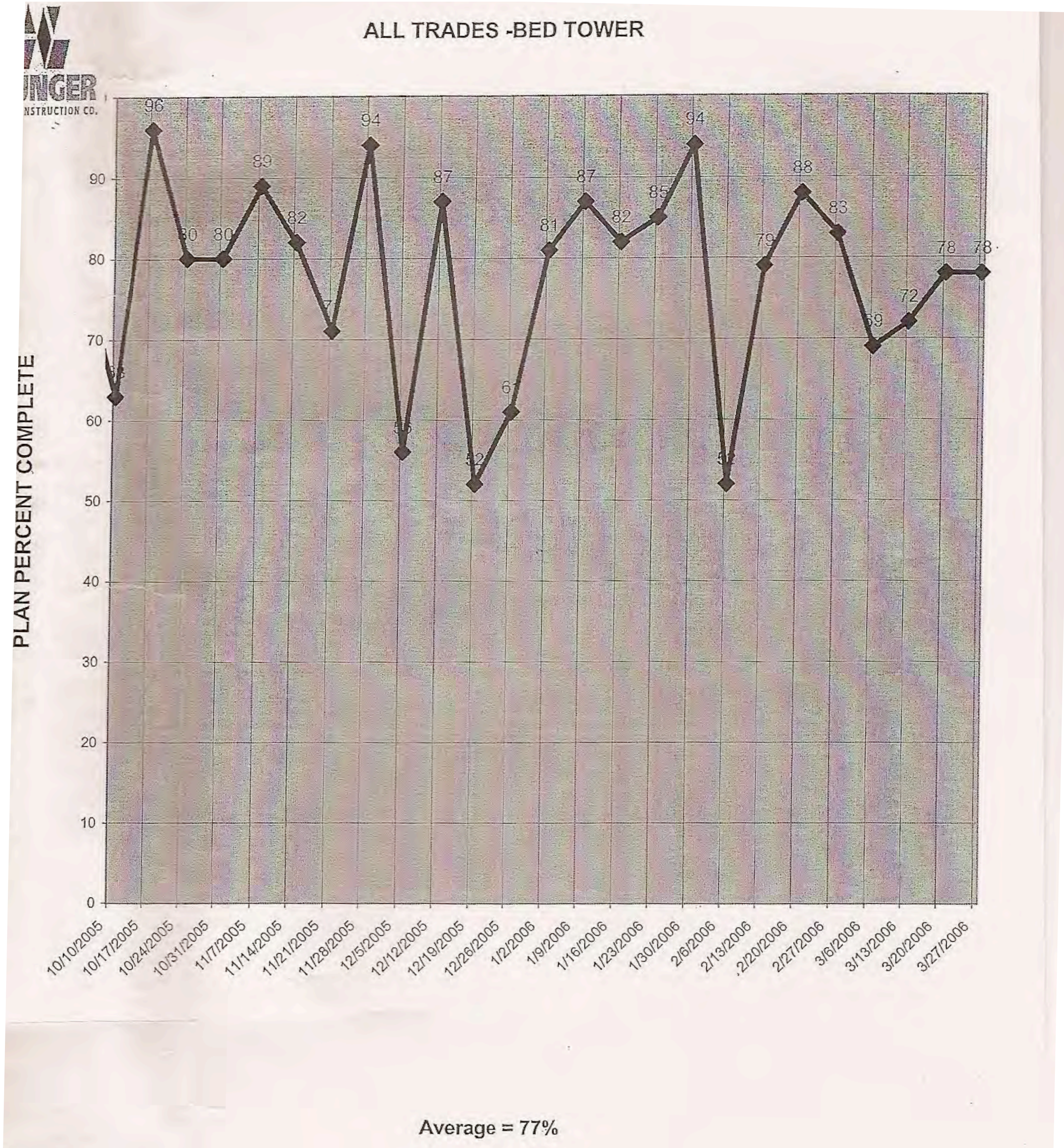
Week of 10/16/00

PPC = 69%

Repeat	Assignment Description: Remember the Five Criteria for Release of Assignments Defined - Sound - Proper Sequence - Right Size - Able to Learn	Responsible Party	M	T	W	T	F	S	Done? Y	Done? N	PPC Analysis: Reasons For Variance / Comments
	Review mock-up drywall dimensions	Randy	x	x	x	x	x		Y		**Wardrobe dimensions changed**
	Review microscope vibration Study	David	x	x	x	x	x			N	
	Review bids - Bid Pack 3	Dena/ Brad	x	x	x	x	x		Y		**Will award next week.**
	Review roofing shops	Jose'	x	x	x	x	x		Y		**Week 1 of 2**
	Complete concrete haunches	Randy	x	x	x				Y		
	Releae order on limestone	Dena	x						Y		
	Re-submit curtainwall support shops	Dick	x	x	x	x	x			N	**Waiting for curtainwall shop drwg.**
	Roof framing: 75% complete	Bob Brue	x	x	x	x	x		Y		
	Submit Phase 2 Millwork Shops	Precision	x	x	x	x				N	
	Fabricate mock-up millwork	Precision	x	x	x	x	x		Y		**Week 2 of 3**
	Re-submit curtainwall shops & structural calcs	Jim Leicht	x	x	x					N	**Middle of next week**
	Finalize review of louver shops	Tony/ David	x	x	x	x			Y		
	Review GL-1 and GL-2	ARC/Jim Leight	x	x	x				Y		

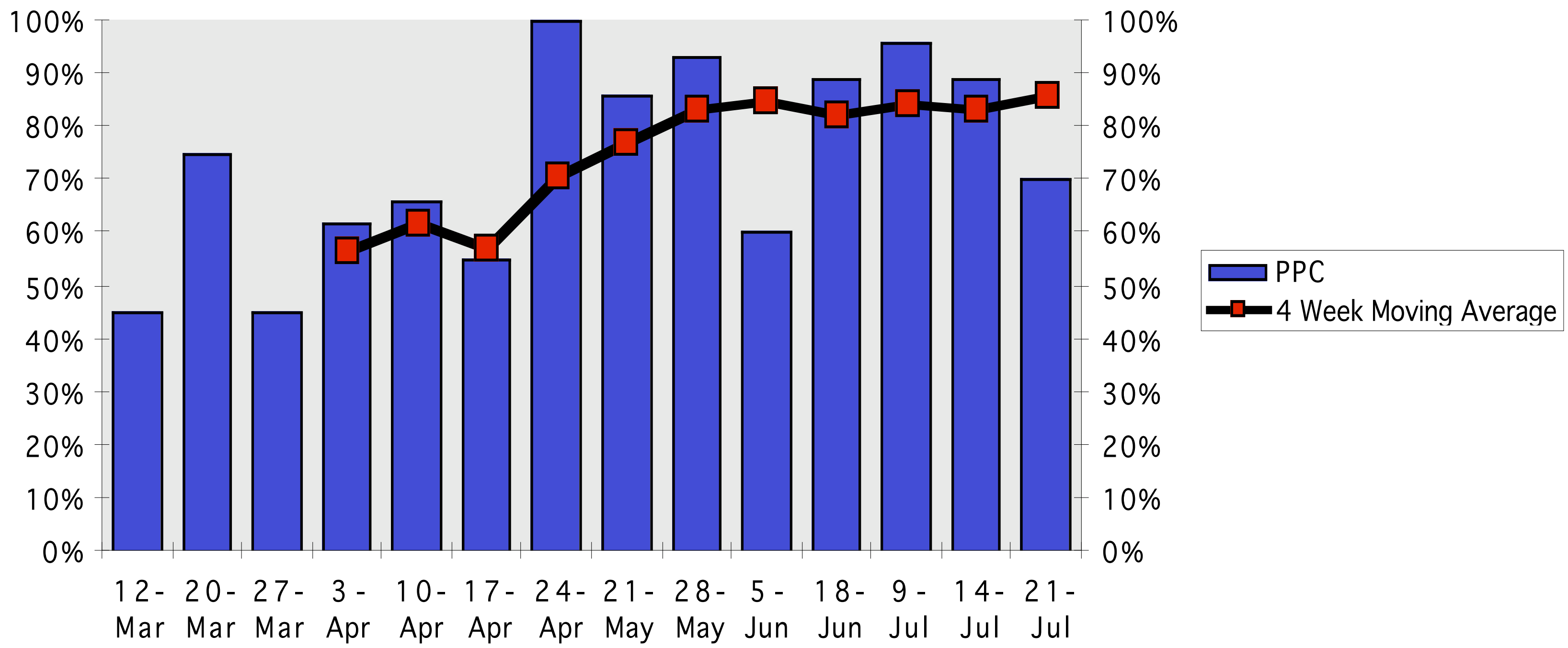
Quality Characteristics of Weekly Work Plans

- Definition
- Soundness
- Sequence
- Size
- Learning

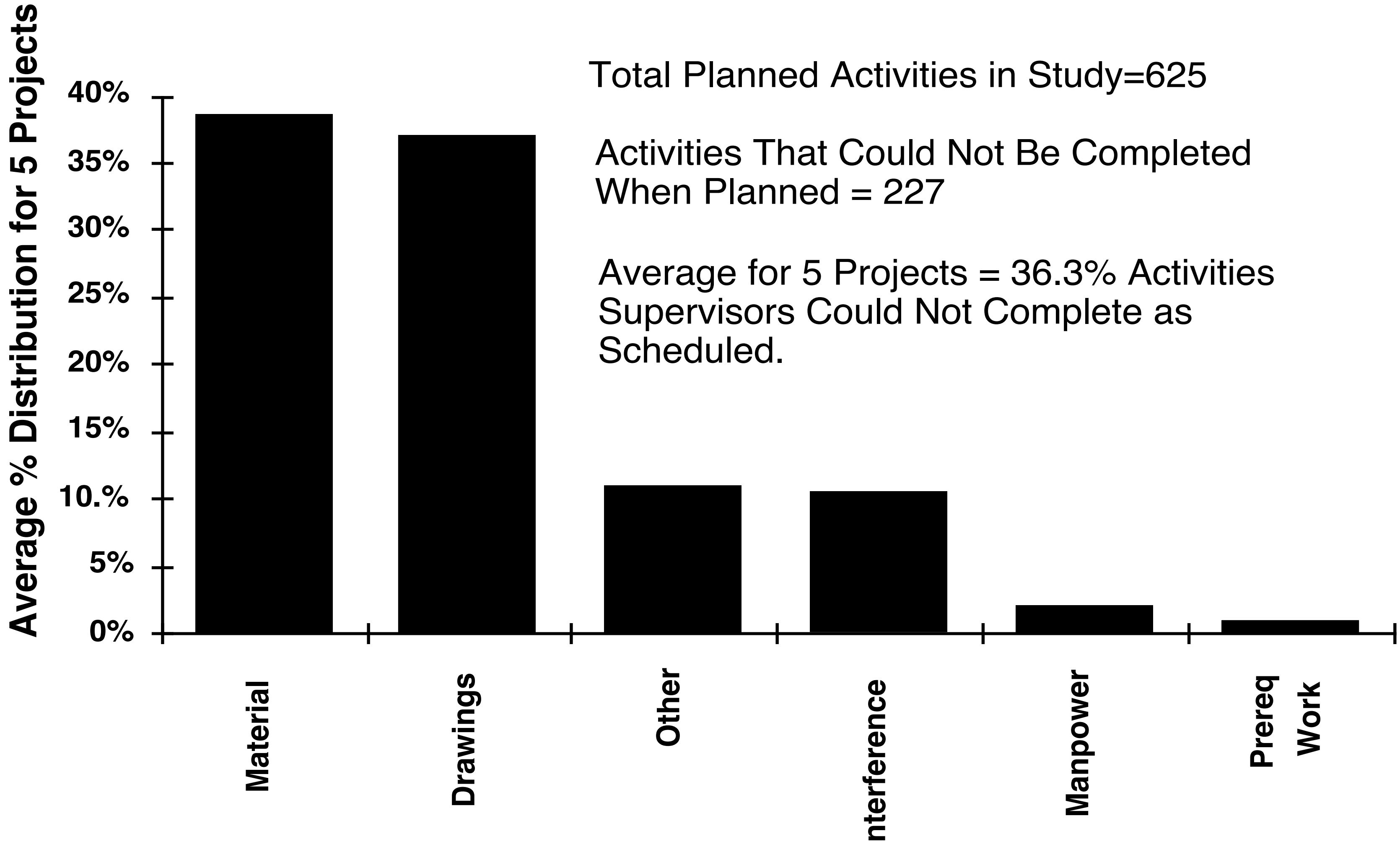

ALL TRADES -BED TOWER
PLAN PERCENT COMPLETE
Average = 77%

Percent Plan Complete (PPC) Chart

Rasacaven: Electrical Power Distribution



Reasons for Plan Failure

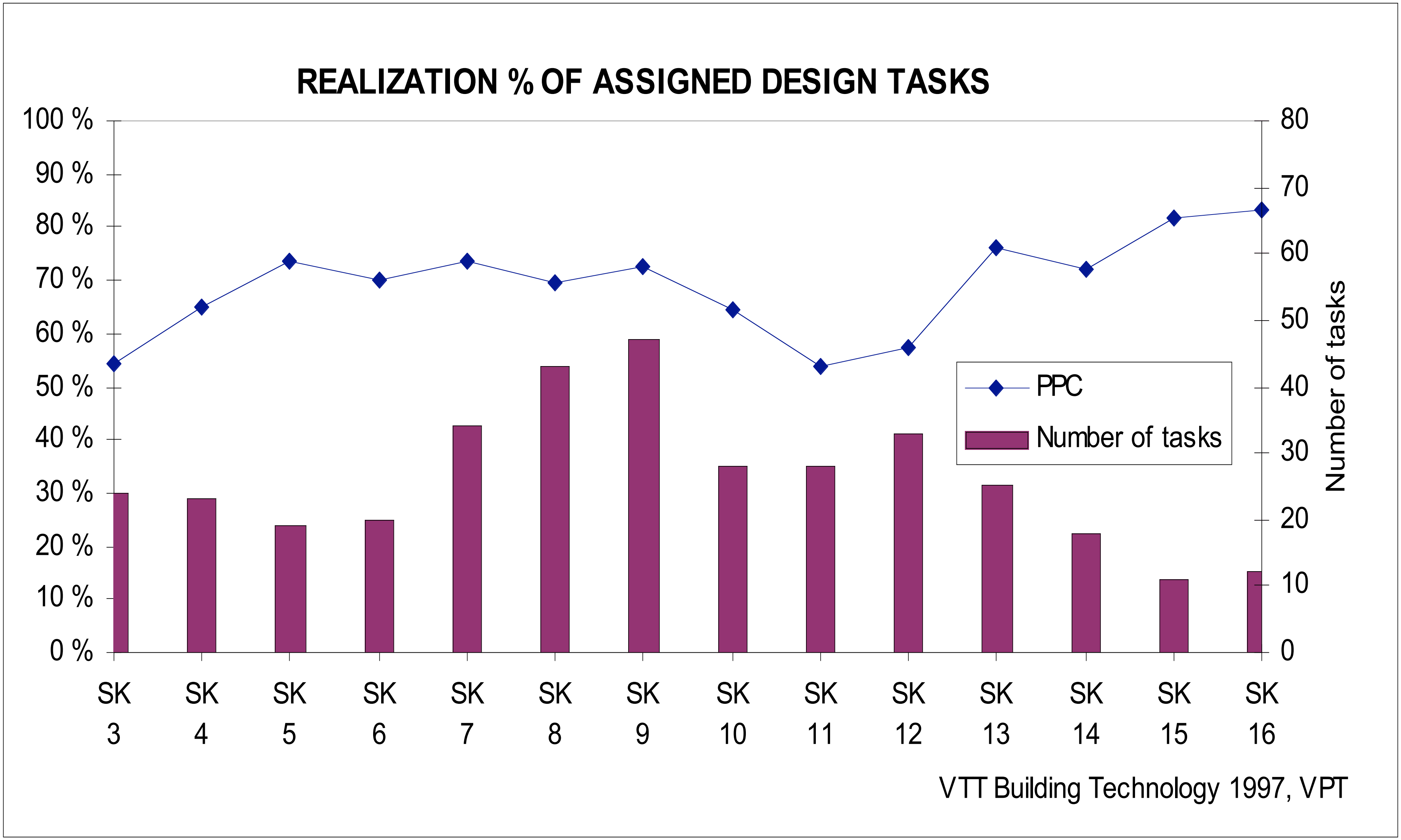


Total Planned Activities in Study=625

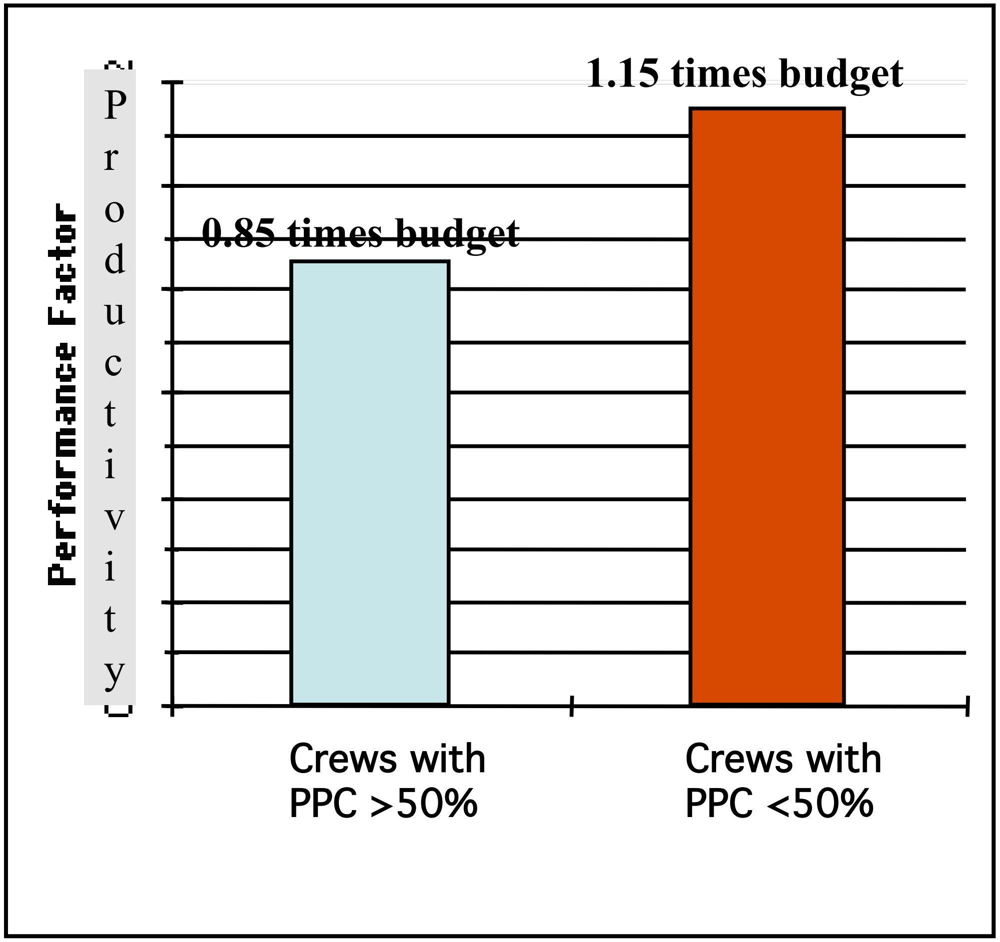
Activities That Could Not Be Completed When Planned = 227

Average for 5 Projects = 36.3% Activities Supervisors Could Not Complete as Scheduled.

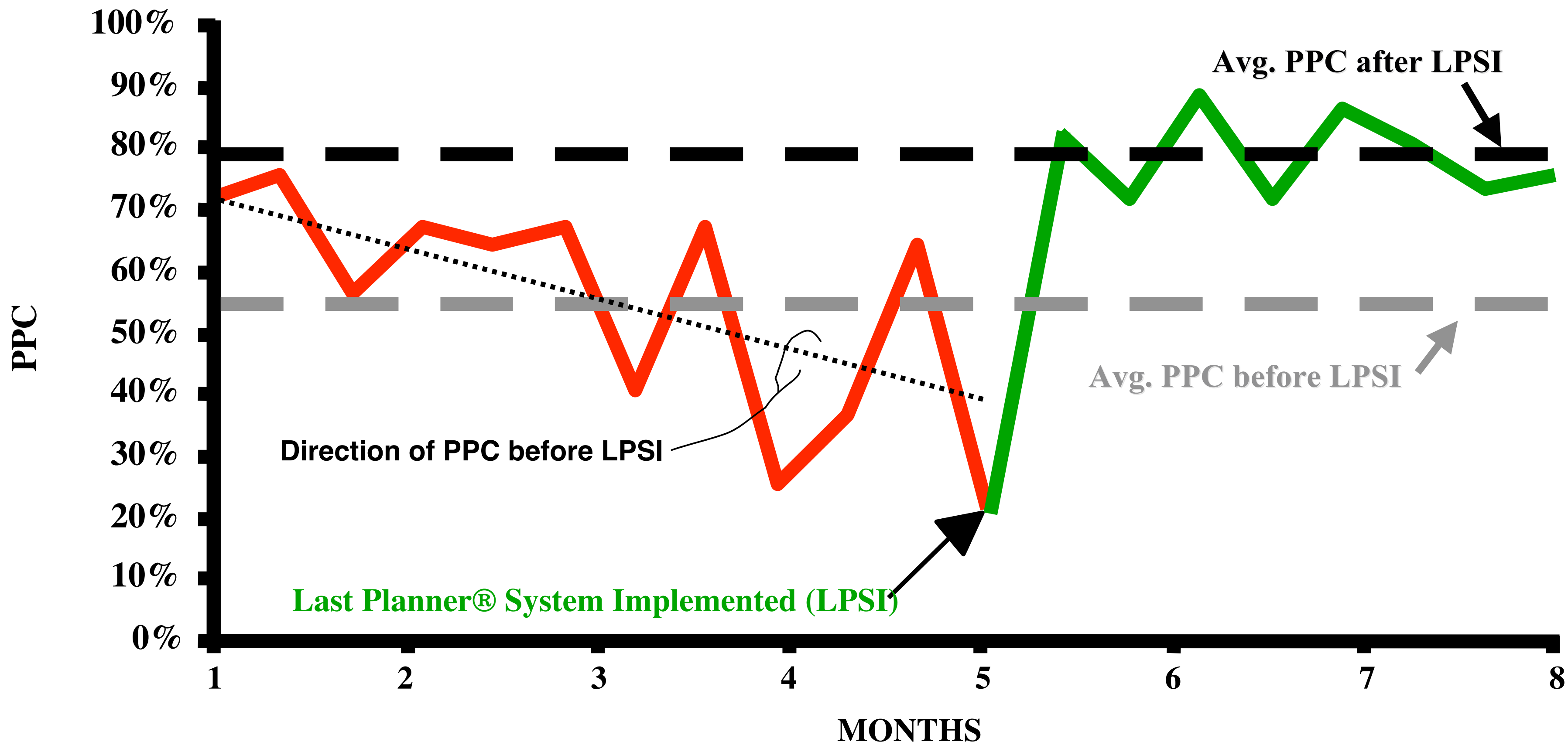
Design PPC: Nokia Project



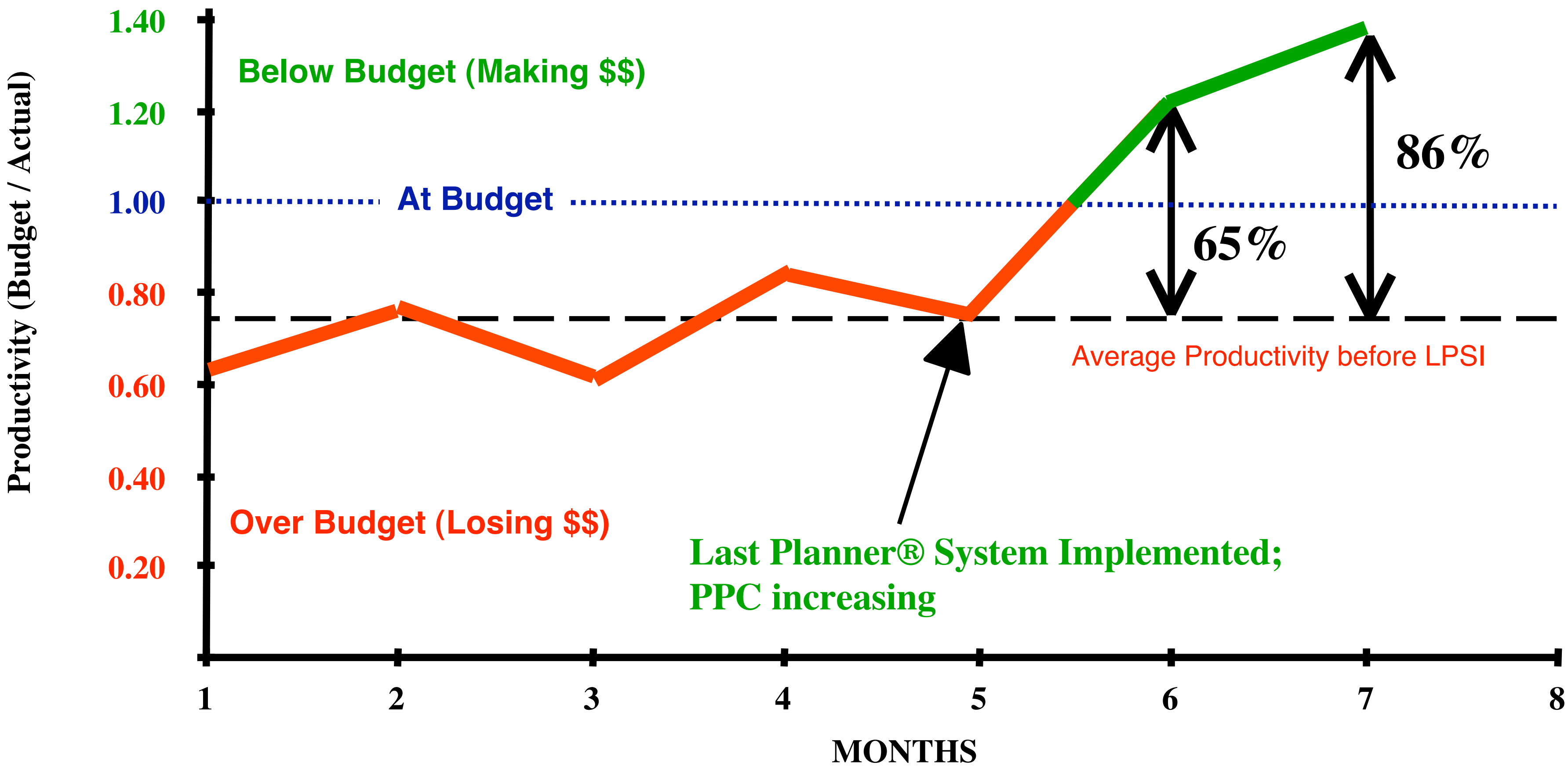
PPC & Productivity



Evolution of PPC



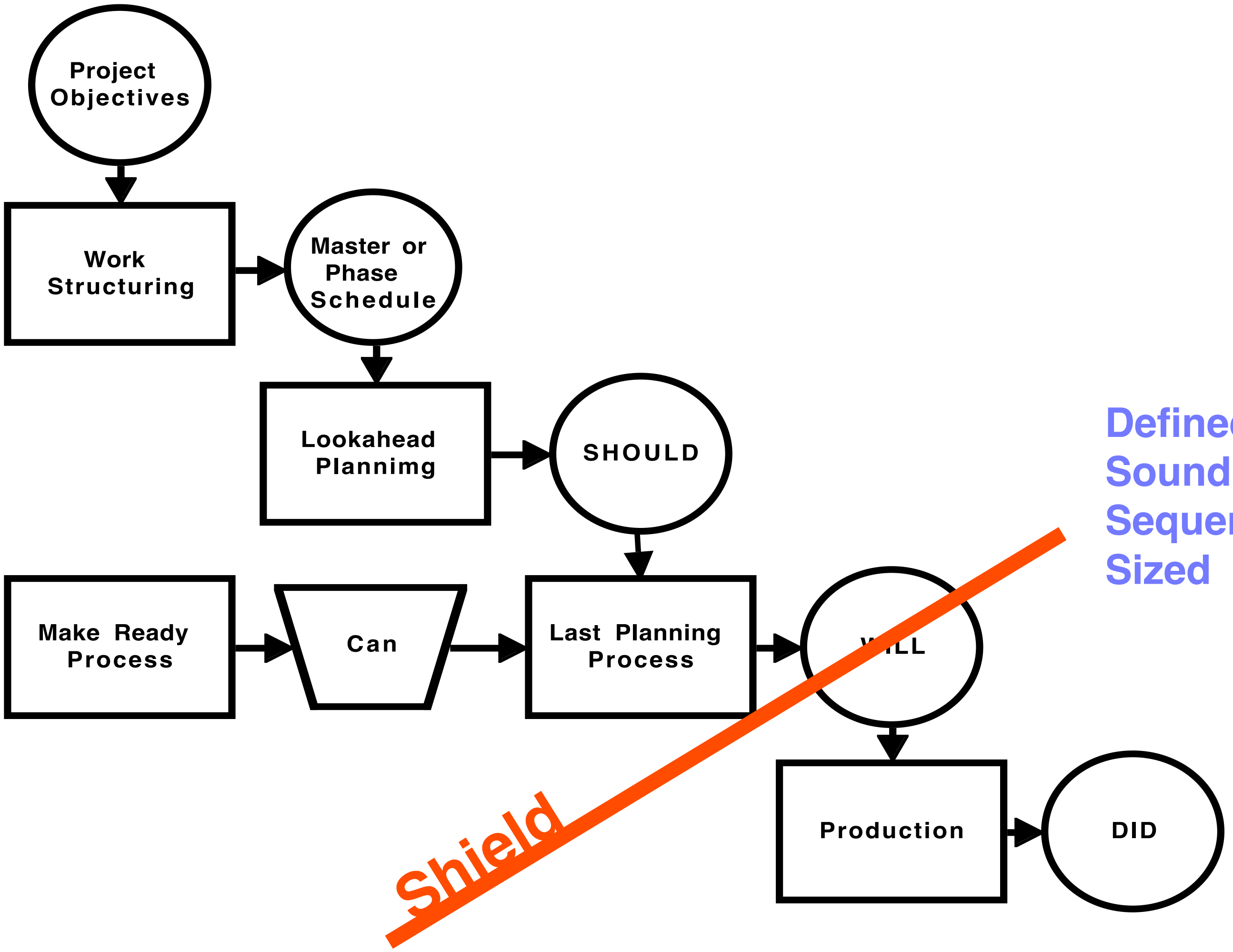
Productivity Evolution



Uncertainty and Variability Can Be Managed

- Reduce variability then go for speed.
- The place to start is by shielding production from flow variability by making only ‘quality’ assignments.
- Managing the remaining variability involves thoughtful location and sizing of inventory and capacity buffers.
- Every ‘workstation’ must make work ready in the right sequence and rate for reliable release to their ‘customer’

The Place To Start

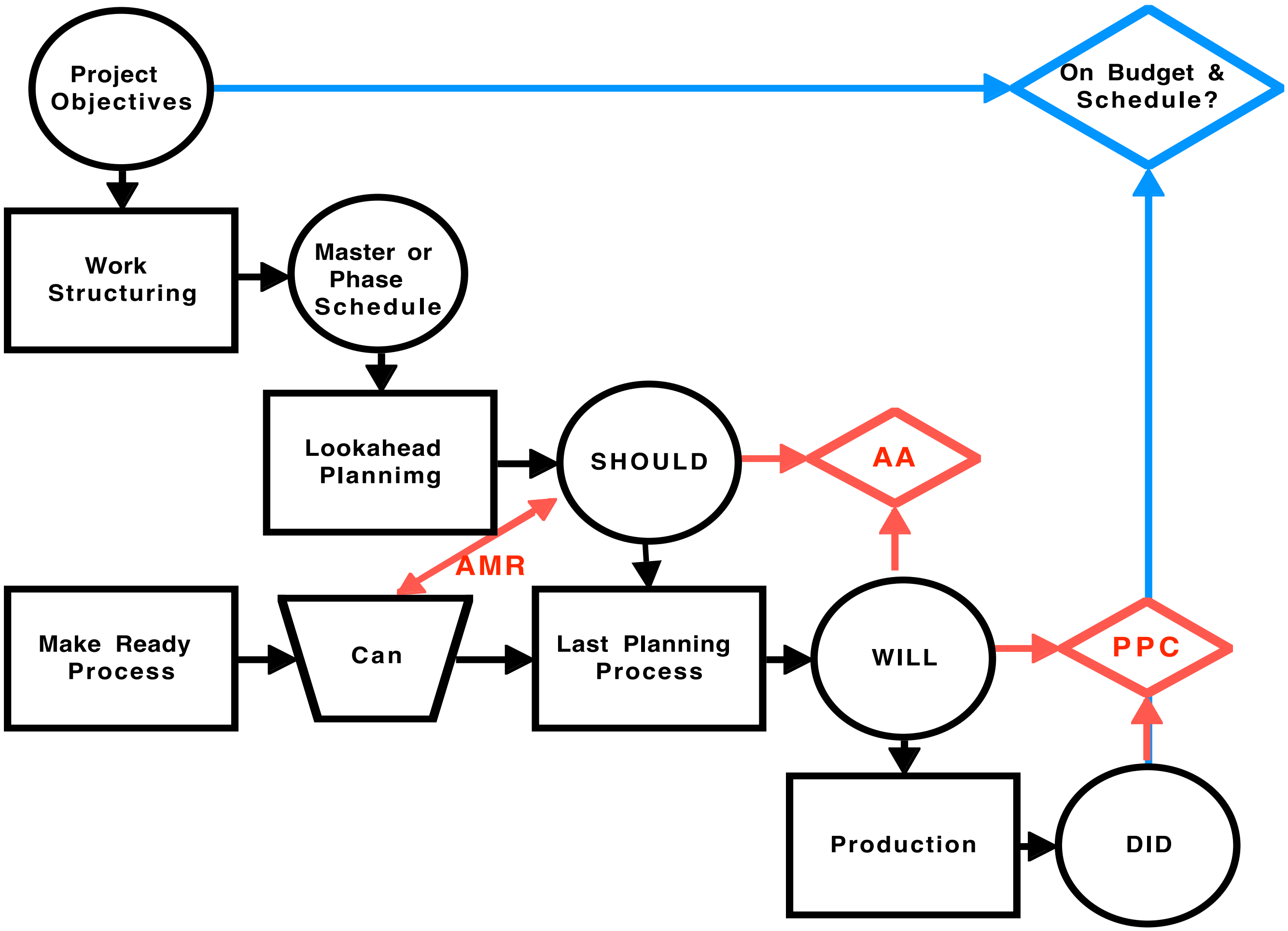


Defined
Sound
Sequenced
Sized

Summary Recommendations for Production Control

- Limit master schedules to milestones and long lead items.
- Produce phase schedules with the team that will do the work, using a backward pass, and making slack explicit.
- Drop activities from the phase schedule into a 6 week lookahead, screen for constraints, and advance only if constraints can be removed in time.
- Learn to make reliable promises.
- Track PPC and act on reasons for failure to keep promises.

Project and Production Controls

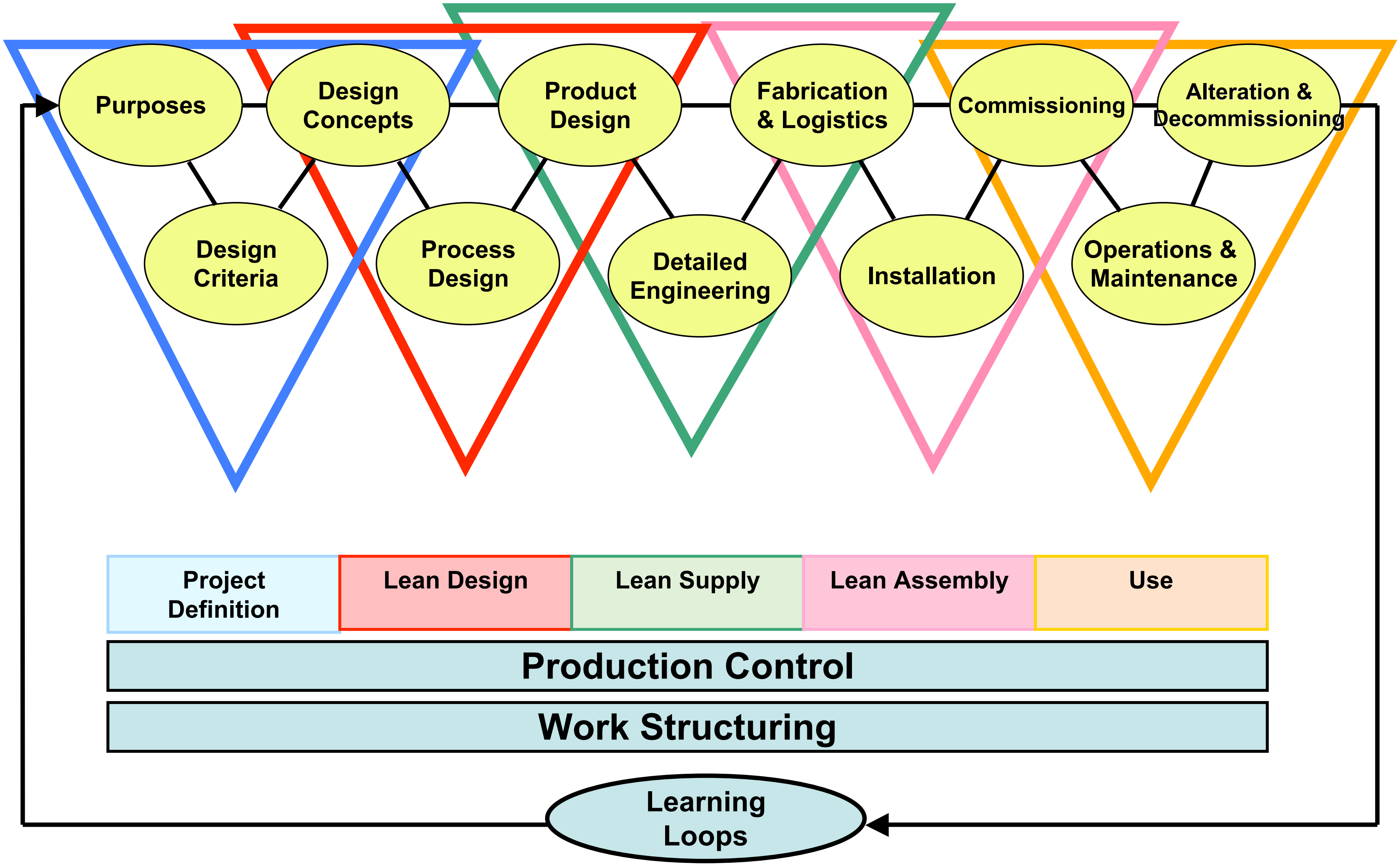


What have you heard so far?

What questions do you have?

Agenda

- Start up
- Work Structuring/Production System Design
  - Airplane Simulation
  - Case Studies in Design of Fabrication Systems: Malling and SpanCrete
  - Case Studies in Design of Site Installation Systems: Brazil (Pereira)
  - Case Study in Design of Supply Systems: Hollow Metal Doors (Boldt)
- The Physics of Production-Work Flow
  - The Parade of Trades Simulation
- The Physics of Coordination
  - Workflow loop
- Production System Control using the Last Planner® System
  - Pull scheduling
  - Lookahead planning
  - Reliable promising
  - Learning
- More about Lean Project Delivery (if time available)
- Implementation/Organization Structuring
- Research directions
- Wrap up



Purposes
Design Concepts
Product Design
Fabrication & Logistics
Commissioning
Alteration & Decommissioning
Design Criteria
Process Design
Detailed Engineering
Installation
Operations & Maintenance
Project Definition
Lean Design
Lean Supply
Lean Assembly
Use
Production Control
Work Structuring
Learning Loops

LC and Safety - Results

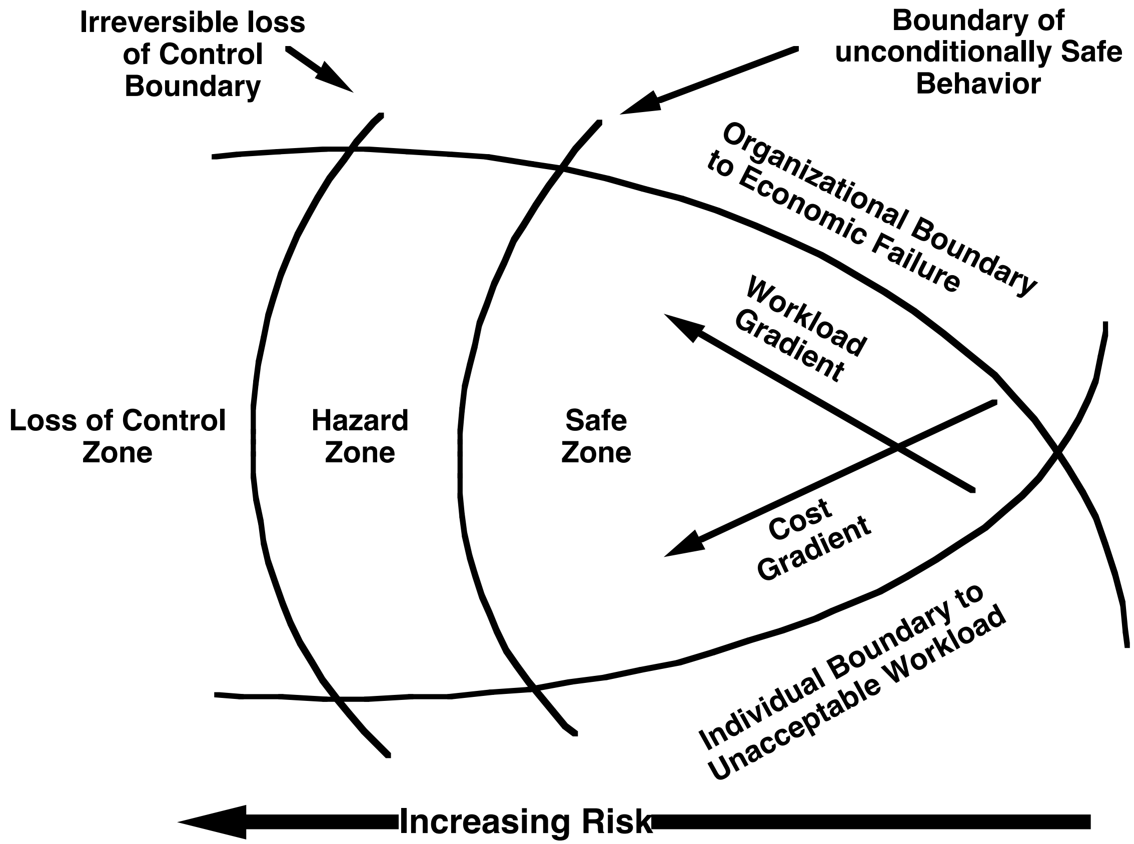
		2001 all year	2002 1. half-year
LC	Working hours	138822	146460
Projects	Accidents causing absence	4	5
	Days of absence due to accidents	-	37
	Incident rate (accidents per 200000 w.hours)	**5,8**	**6,8**
	Absence rate (preliminary results)	-	1,9
Ordinary	Working hours	426984	150127
Projects	Accidents causing absence	42	15
	Days of absence due to accidents	-	110
	Incident rate (accidents per 200000 w.hours)	**19,7**	**20,0**
	Absence rate (preliminary results)	-	5,4

P=1.3%

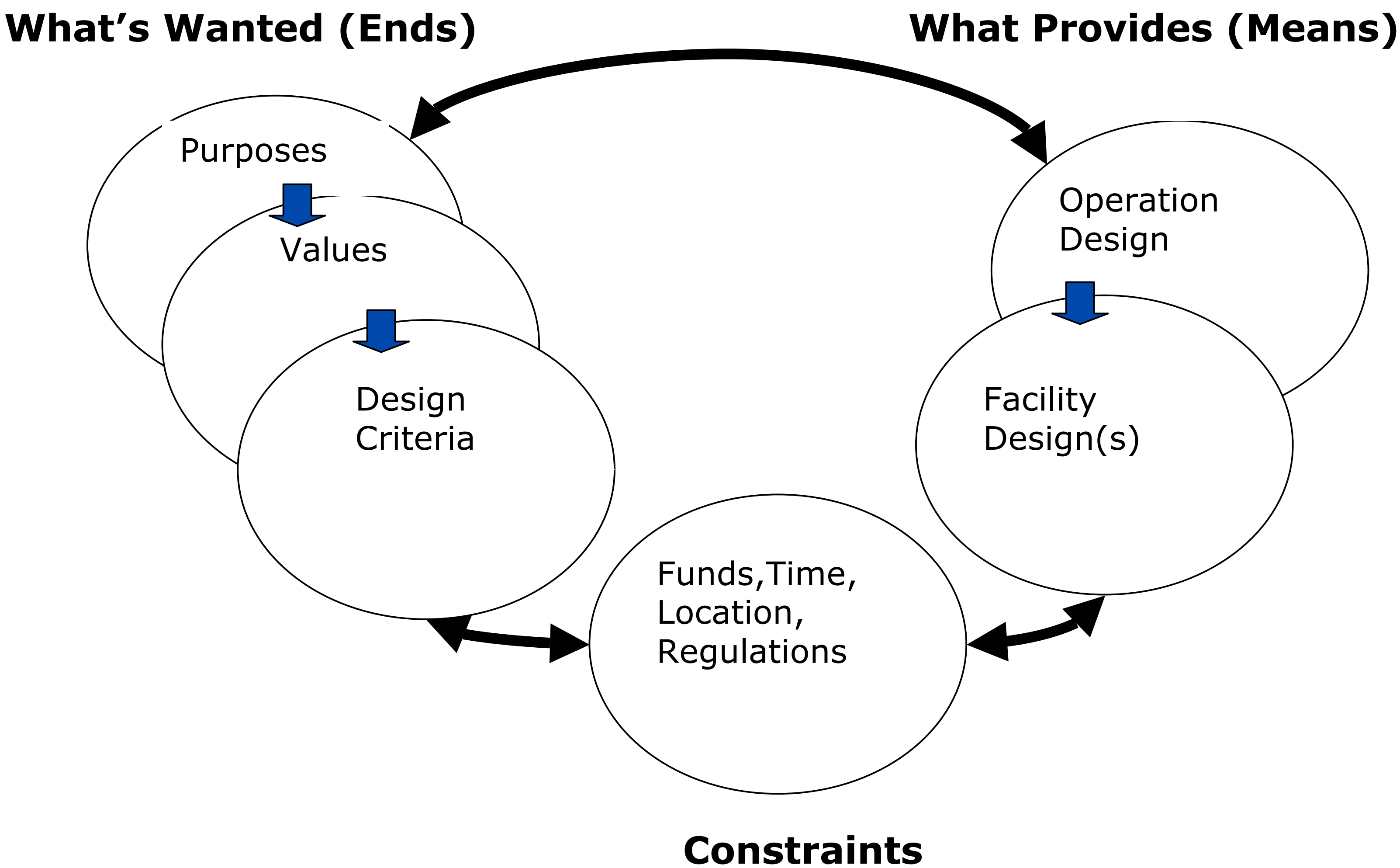
P=2.9%

The results are significant!

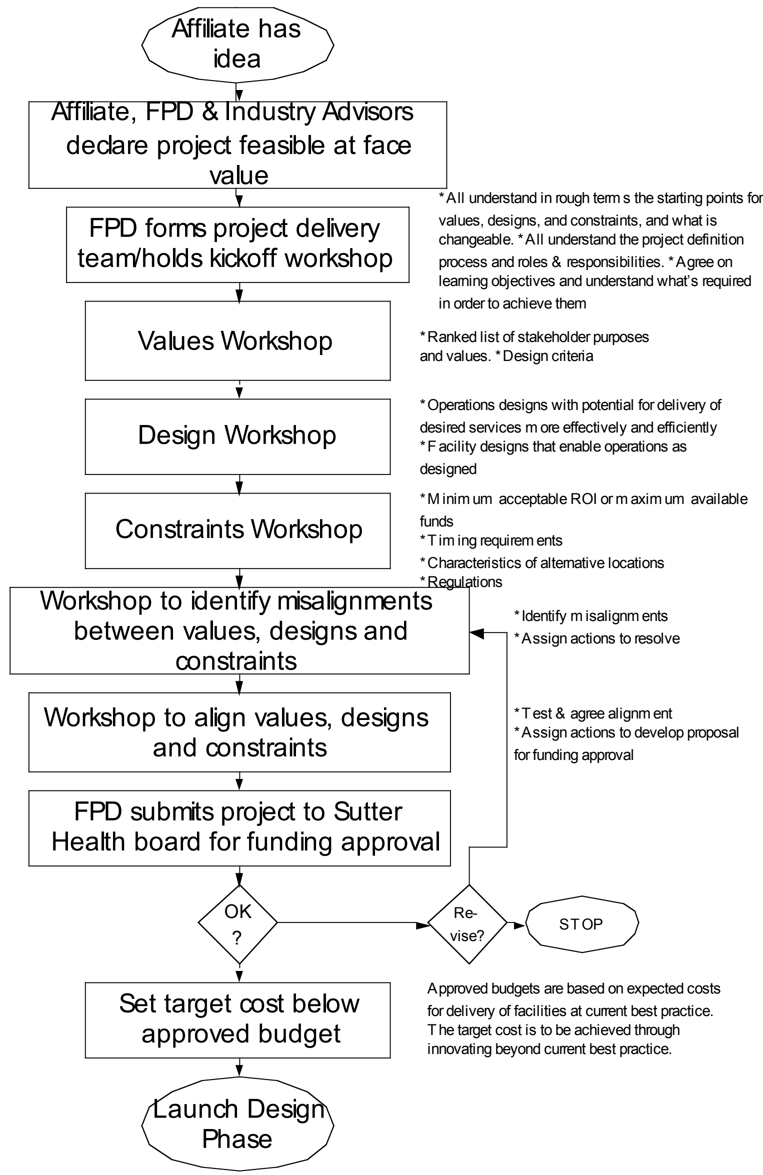
A new approach to safety



Project Definition Process (setting the target)



Project Definition Process



Notes:
1. All workshops are one day or less in duration.
2. Preparation occurs between workshops and other process steps.
3. Multiple workshops may be required to achieve alignment.

Lean Design: An Overview

Organize in Cross Functional Teams	* Involve downstream players in upstream decisions * Alternate between all-group meetings and task force activities * Create and exploit opportunities to increase value in every phase of the project
Pursue a set based strategy	* Select from alternatives at the last responsible moment * Share incomplete information * Share ranges of acceptable solutions
Structure design work to approach the lean ideal	* Simultaneous design of product and process * Consider decommissioning, commissioning, assembly, fabrication, purchasing, logistics, detailed engineering, and design * Shift detailed design to fabricators and installers
Minimize Negative Iteration	* Pull scheduling * Design Structure Matrix * Strategies for managing irreducible loops
Use Last Planner System of Production Control	* Try to make only quality assignment * Make work ready within a lookahead period * Measure PPC * Identify and act on reasons for plan failure
Use technologies that facilitate lean design	* Shared geometry; single model * Web based interface

Lean Supply To Do's

- Reduce the number of suppliers and engage them in pursuit of the lean ideal.
- Shift detailed engineering to fabricators and installers.
- Integrate detailed engineering from multiple specialists in 3D models.
- Drive fabricating equipment with model data.
- Reduce lead times so more materials can be pulled to site from further back in supply chains.
- Structure logistics so materials can be pulled to site in small batches.
- Monitor and improve the quality and timeliness of supplier deliveries

Lean Assembly To Do's

- Simplify site installation to final assembly and test
- Strive for one-touch material handling
- Pull from off-site suppliers
- Structure work in continuous flow processes
- Minimize total head count of site personnel
- Use in-process inspection
- Strive for zero defects through progressive completion and rapid learning

Traditional versus Lean

Traditional

- Decisions are made sequentially by specialists and 'thrown over the wall'
- Product design is completed, then process design begins
- Not all product life cycle stages are considered in design
- Activities are performed as soon as possible

Lean

- Downstream players are involved in upstream decisions
- Product and process are designed together
- All product life cycle stages are considered in design
- Activities are performed at the last responsible moment

Traditional versus Lean

- Separate organizations link together through the market, and take what the market offers
- Participants build up large inventories to protect their own interests
- Stakeholder interests are not aligned
- Learning occurs sporadically

- Systematic efforts are made to reduce supply chain lead times
- Buffers are sized and located to perform their function of absorbing system variability
- Stakeholder interests are aligned
- Learning is incorporated into project, firm, and supply chain management

Research Initiative: Target Costing

Glenn Ballard

Project Production Systems Laboratory

University of California, Berkeley

Target Costing

- …strives to deliver more value for the money to clients and other stakeholders.
- …strives to reduce the waste and rework in the design-estimate-redesign cycle.
- ...requires a fundamental shift in thinking from ’expected costs’ to ’target costs’.
- …necessarily involves cross functional teams. No one person has all the knowledge.
- …cries out for an integrated product/process /cost model.

Setting the Target Cost in the Feasibility Study

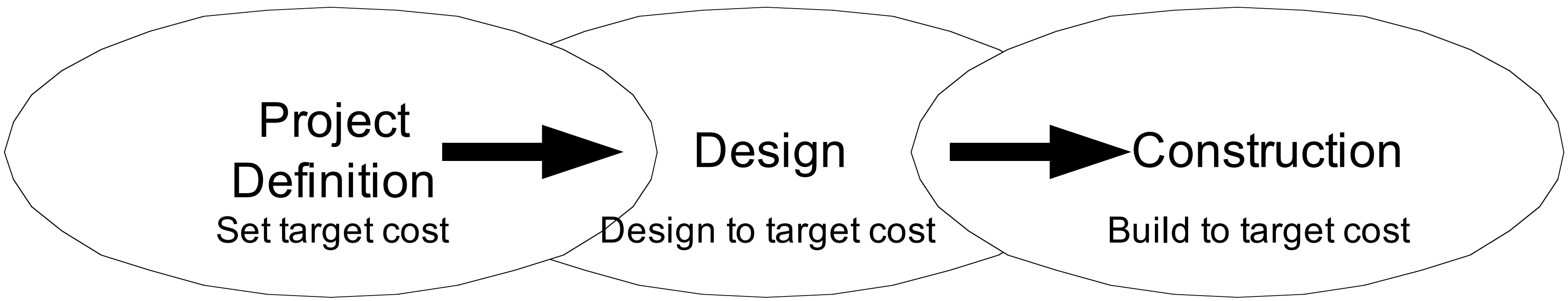
- Determine minimum acceptable ROI or maximum available funds (allowable cost from business plan).
- Select cross functional team.
- Determine and rank stakeholder values.
- Scope the facility(s) that will deliver the values.
- Determine the expected cost if the facility(s) were provided **at current best practice**.
- If expected cost>available funds or violates ROI, adjust scope by sacrificing lesser ranking values—until the project delivery team is confident minimum program can be delivered for maximum available funds.
- Submit project budget to board for approval.
- Set target cost below budget to drive innovation beyond current best practice.
- Agree if/how to divide budget underruns between client and project team.

OR

Setting the Target Cost in the Feasibility Study

- Determine minimum acceptable ROI or maximum available funds (allowable cost from business plan).
- Select cross functional team.
- Determine and rank stakeholder values.
- Scope the facility(s) that will deliver the values.
- Determine the expected cost if the facility(s) were provided **at current best practice**.
- If expected cost>available funds or violates ROI, adjust scope by sacrificing lesser ranking values.
- Submit project budget to board for approval.
- *Set target scope above minimum program to drive innovation and deliver greater value--specify on ranked list of values.*
- *Agree if/how to reward the team for achievement of target value.*

Target Costing by Project Phase



Target Cost Model

Legend:	Const TOTAL per SF	D-B TOTAL per SF
Worth (Target)		
Current Estimate	89.33	94.12

Project:	Fieldhouse Expansion
Location:	St. Olaf College Northfield MN
Phase of Design:	Schematic Target
Date:	June 21, 2001

Construction	+	Owner Reserves	+	Escalation	=	Construction TOTAL	Design-Build TOTAL
9,840,302		343,115				10,183,417	10,729,883

Incl Design at $504,886+41600

NOTES:

Bldg. Type:	Recreational
Target (SQFT)	114,000
Floors:	Single story plus mezzanines

SITE WORK	BUILDING
594,500	9,245,802

SITE WORK		SHELL		INTERIOR		MECHANICAL		ELECTRICAL		SPECIAL		GENERAL	
Site GC OH&P		SHELL	4,334,488	INTERIOR	1,710,386	MECHANICAL	1,111,402	ELECTRICAL	794,890	SPECIAL	706,862	GENERAL	587,774
G10 Site Prep, Demo & Excav	146,500	A10 Foundation A20 Basement	1,006,004	C10 Interior Construction	528,427	D20 Plumbing	85,927	D5010 Service and Distribution	739,390	E10 Specialties & Equipment	492,534	Z1010 Project Administration	
G20 Site Improvements	373,000	B10 Superstructure	1,218,797	C20 Stairs	62,639	D30 HVAC	824,160	D5020 Lighting & Branch Wiring		E20 Furnishings Fixed/Movable	34,000	Z1030 General Conditions	
G30+40 All Utilities	75,000	B20 Exterior Closure	2,007,061	C30 Interior Finishes	1,069,320	D40 Fire Protection	109,740	D5030 Security Comm/Data		F10 Special Construction	89,520	Z1060 Fee	
G90 Other Site Structures		B30 Roofing	102,626	D10 Conveying	50,000	Testing and Special Mech	91,575	D5090 Other Electrical	55,500	F20 Selective Demolition	90,808	Z20 Risk and Contingency	587,774

Applying the Cardinal Rule

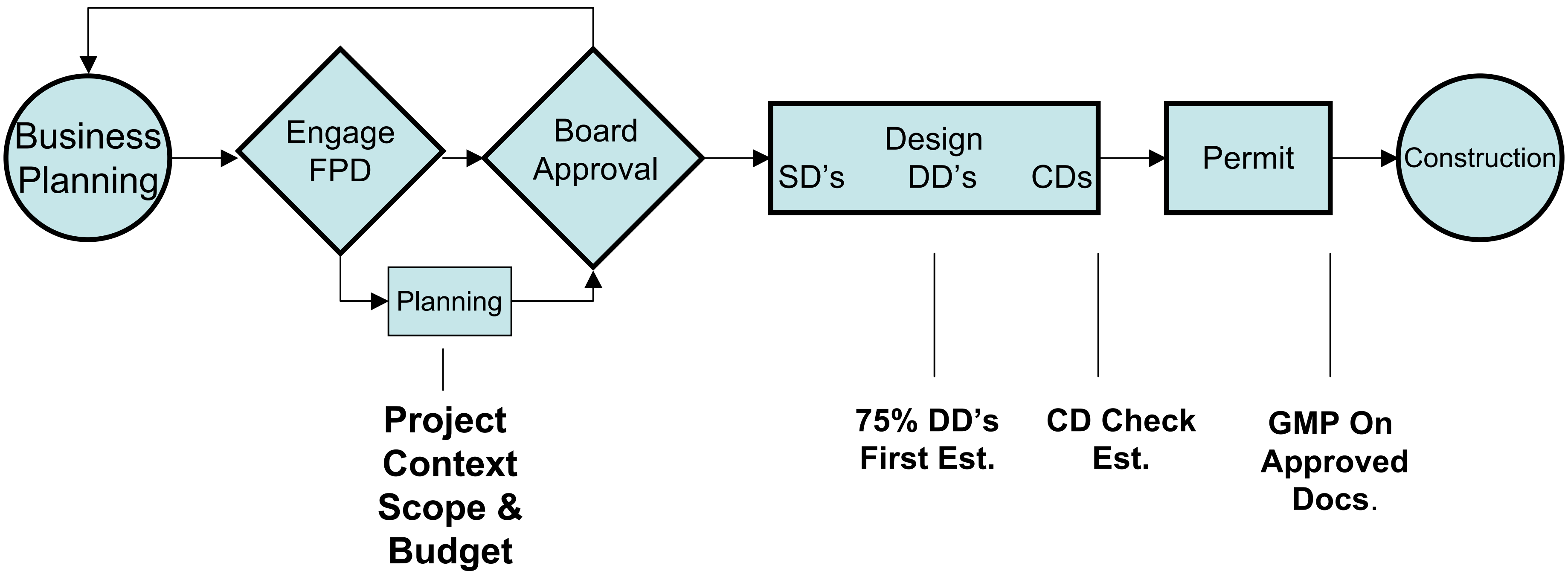
The Cardinal Rule

The Target Cost of the Facility Can Never Be Exceeded

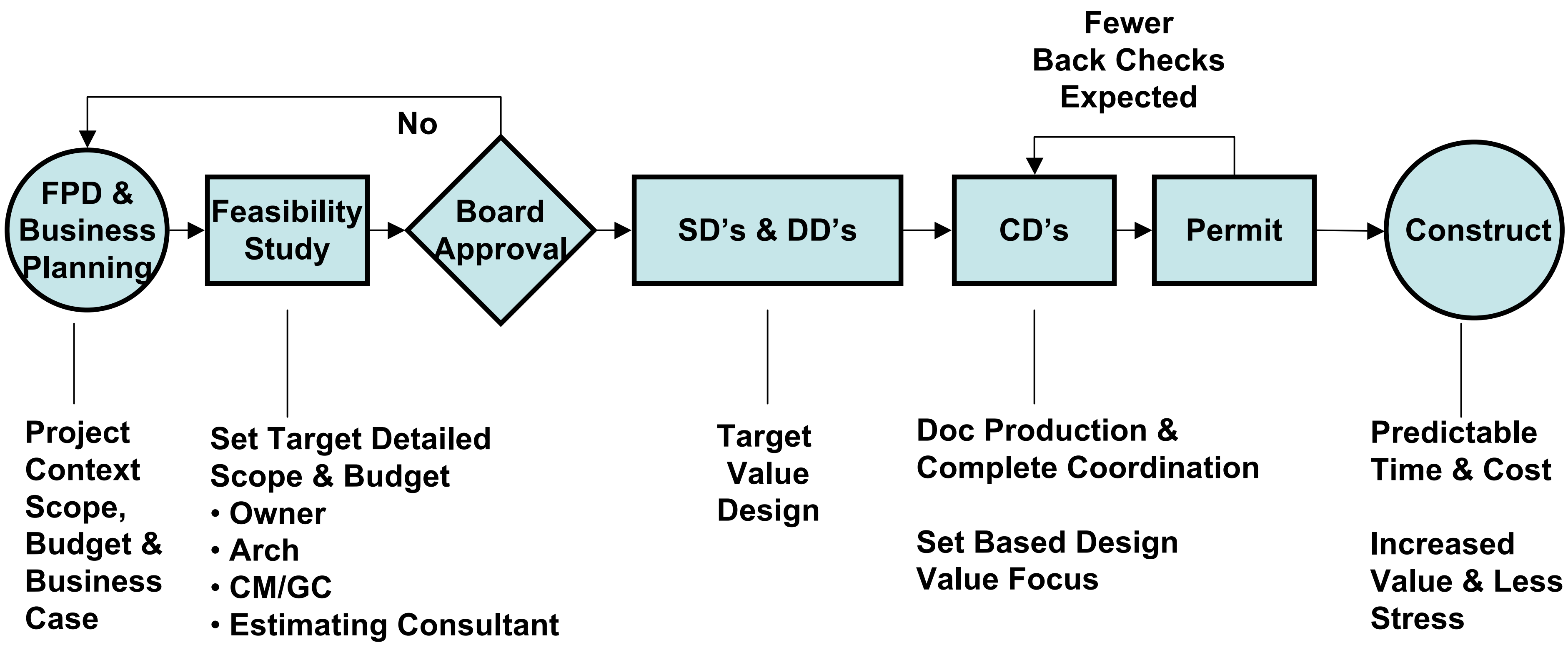
- Ensuring that whatever target costs increase somewhere in the facility, costs are reduced elsewhere by an equivalent amount without compromising program and quality.
- Refusing to add scope to a project that will overrun the target cost.
- Managing the transition from design to construction to ensure the target cost is never exceeded.

	St. Olaf Fieldhouse	Carleton College Recreation Ctr
Completion Date	August 2002	April 2000
Project Duration	14 months	24 months
Gross Square Feet	114,000	85,414
Total Cost (incl. A/E & CM fees)	$11,716,836	$13,533,179
Cost per square foot	$102.79	$158.44

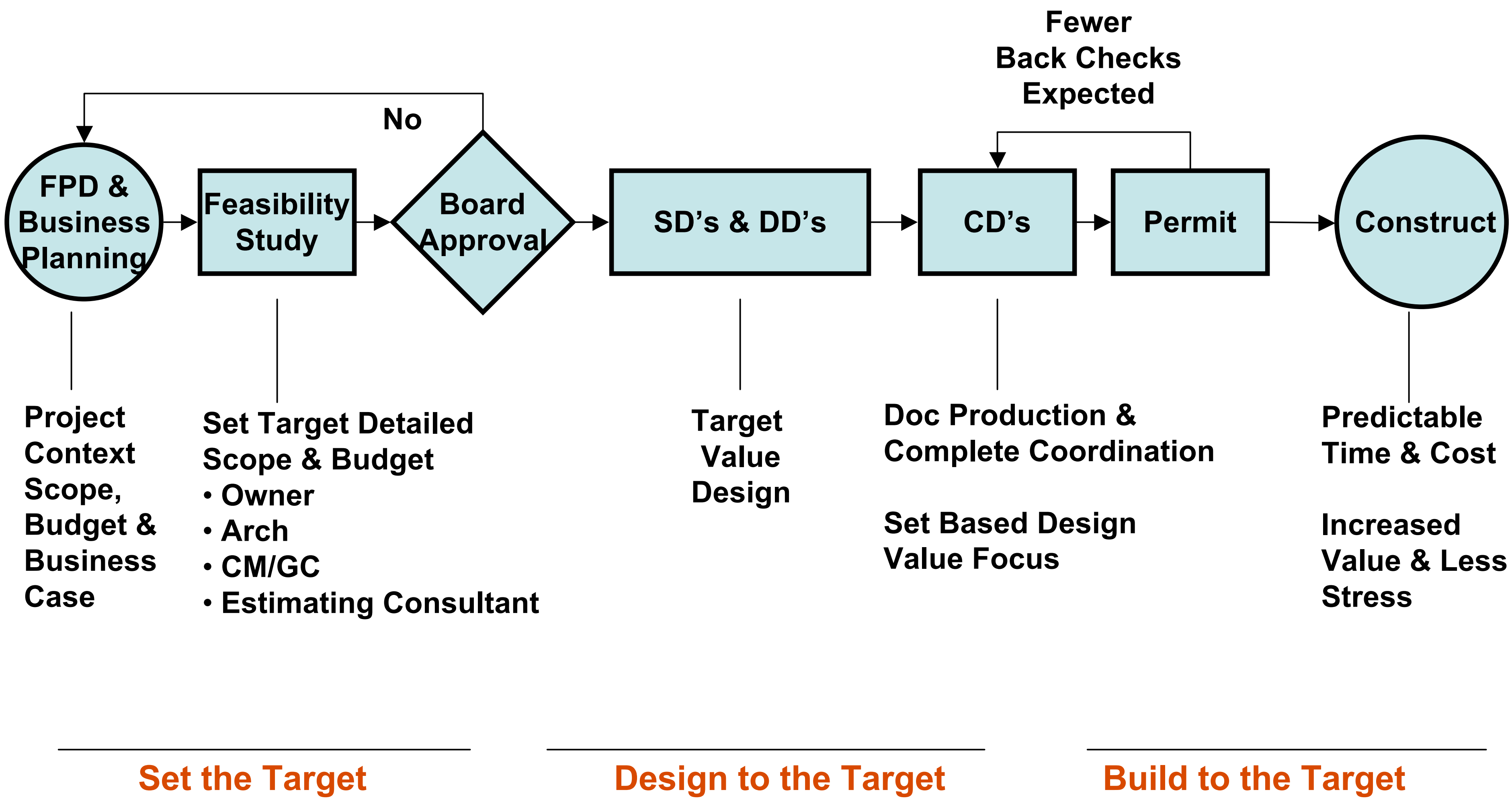
Sutter Health's Old Process



Sutter Health's New Process



Sutter Health's New Process



Current Benchmark for Target Value Design

- The client evaluates the business case before deciding if to fund a feasibility study.
- The feasibility study involves all key members of the team that will deliver the project if the study findings are positive.
- The client is an active and permanent member of the project delivery team.
- The feasibility study report includes a detailed budget aligned with scope.
- Cost estimating is done continuously through intimate collaboration between design professionals and cost modelers—‘over the shoulder estimating’.
- All team members understand the business case and stakeholder values.
- The Last Planner system is used to coordinate the actions of team members.

Changes required for the current TVD benchmark

- Clients spend more in the project definition phase of projects than they traditionally have done.
- The major players on the project delivery team are not selected through competitive bidding.
- Architects relinquish their privileged access to clients.
- Design professionals embrace collaboration with suppliers and builders.
- Suppliers and builders understand and respect designers and learn how to contribute and participate in project definition and design processes.
- General contractors allow specialty contractors a seat at the table.
- The incentives of all team members are aligned with pursuit of project objectives.

Special efforts required for implementing the current TVD benchmark

- Clear statements up front, plus frequent reminders about the nature and extent of the changes required in attitudes and behaviors.
- Empowering and requiring team members to declare breakdowns; i.e., to speak up when they perceive that agreed criteria are not being followed, that value is being sacrificed or waste is being generated.
- Including team players in user group meetings and other occasions where they can hear and see for themselves what is of value to the customer.
- Education, coaching and building trust among team members.

Tools and Techniques

- Space planning based on contents and use, not historical standards
- Reverse phase scheduling
- Fixed schedules for user group meetings
- Room data sheets as records of agreements, signed off by users
- Weekly coordinating meetings with strict documentation of commitments

Going Beyond the Current Benchmark

1. **How best to assure that the use of the facility is explored and agreed upon before attempting to design the facility itself?**

2. **Does the investment in upstream processes pay off in a) the avoided costs of bad projects that are not allowed to continue, b) in the increase in value from more effective processes for articulating values and controlling design and construction to the delivery of those values, c) in the reduction in waste from incomplete and inaccurate drawings, from duplicated efforts, from rework, d) from more reliable delivery to quality, time and cost expectations, e) from the ability to respond more quickly to changes and discoveries?**

3. **How best size and manage contingency to achieve target costs?**

4. **Is an evergreen, ranked list of stakeholder values beneficial and feasible as a tool for value management?**

Going Beyond the Current Benchmark

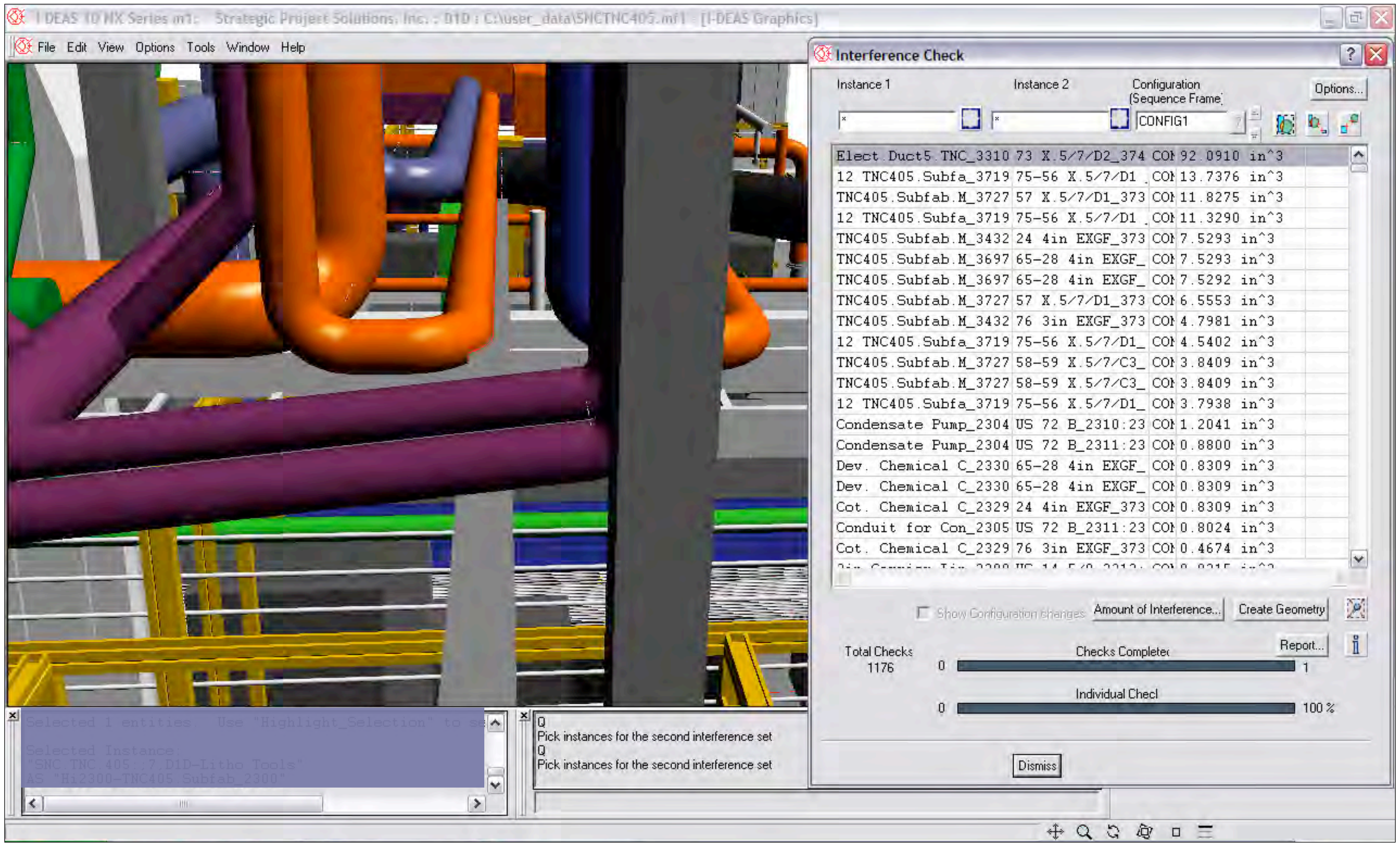
5. **Is co-location of project delivery team members beneficial and feasible? How do we collaborate when team members cannot co-locate regularly?**

6. **How to improve on current benchmarks as regards the integration of cost modeling and designing?**

7. **Is it better for specialty contractors to be engaged on a design-assist or a design-build basis?**

8. **What information technologies can be used to support Target Costing practices; e.g., integrating product, process and cost models?**

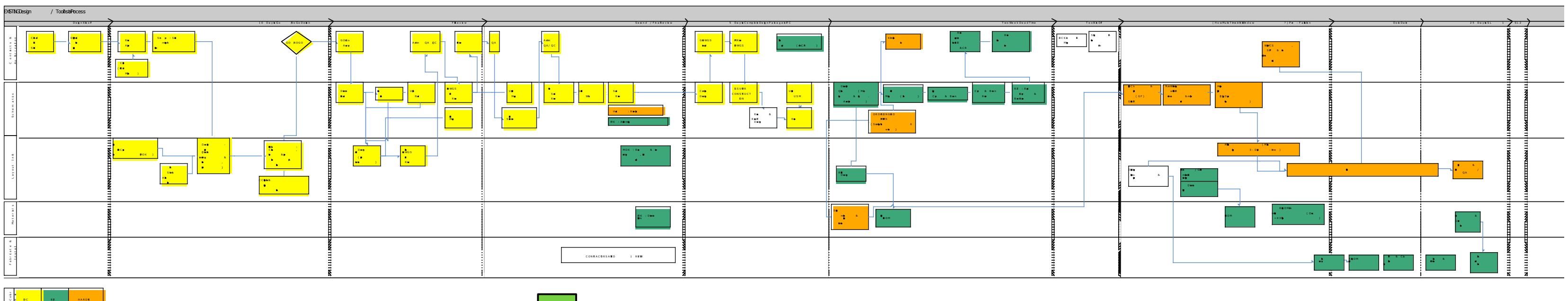
Clash Analysis using Digital Prototyping

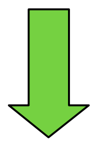


A clash analysis performed by the I-DEAS software checked 155,961 potential conflicts in minutes; several unanticipated clashes between the electrical and mechanical routing designs were discovered and eliminated prior to the development of construction drawings.

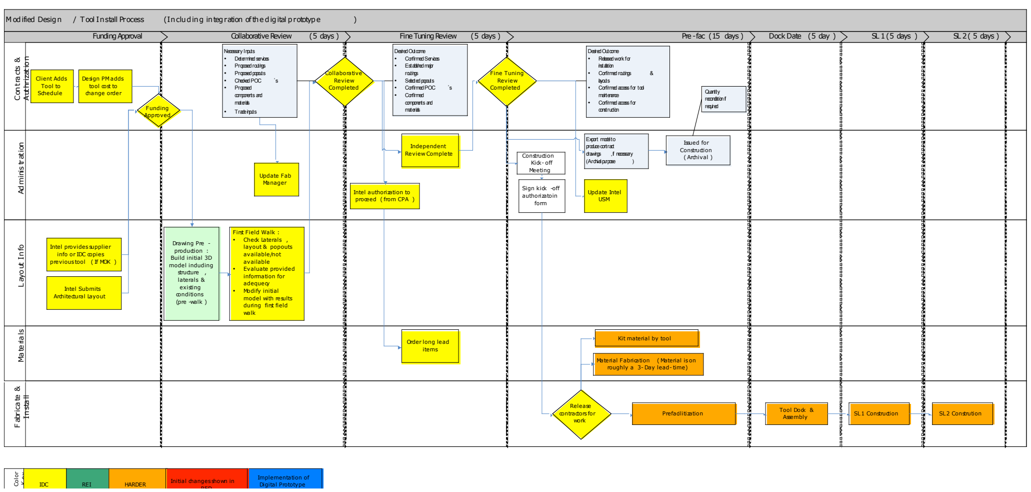
Process Re-engineering

Current





Future



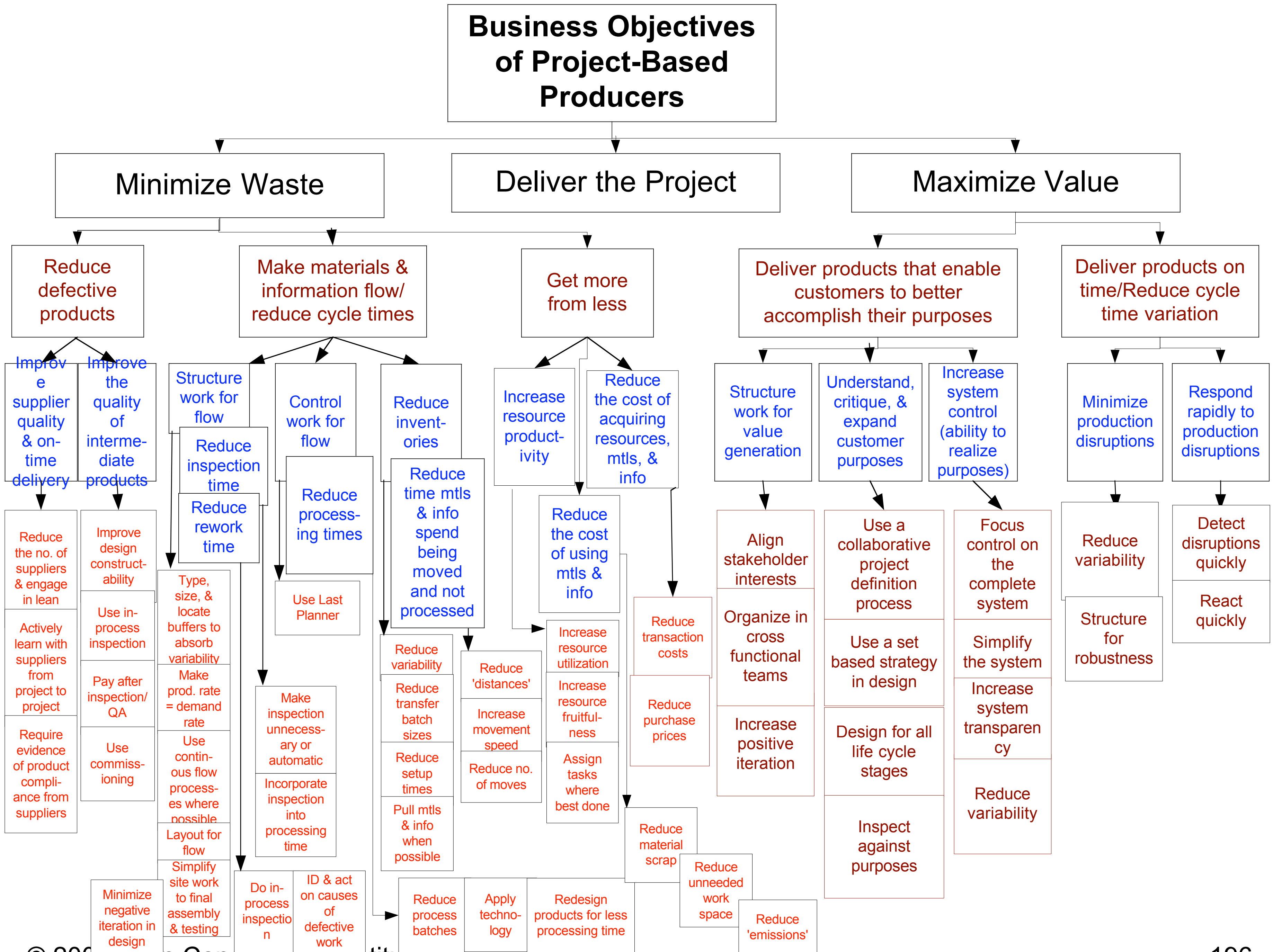
Developed through collaborative workshops

Result:

105 Days → 40 Days

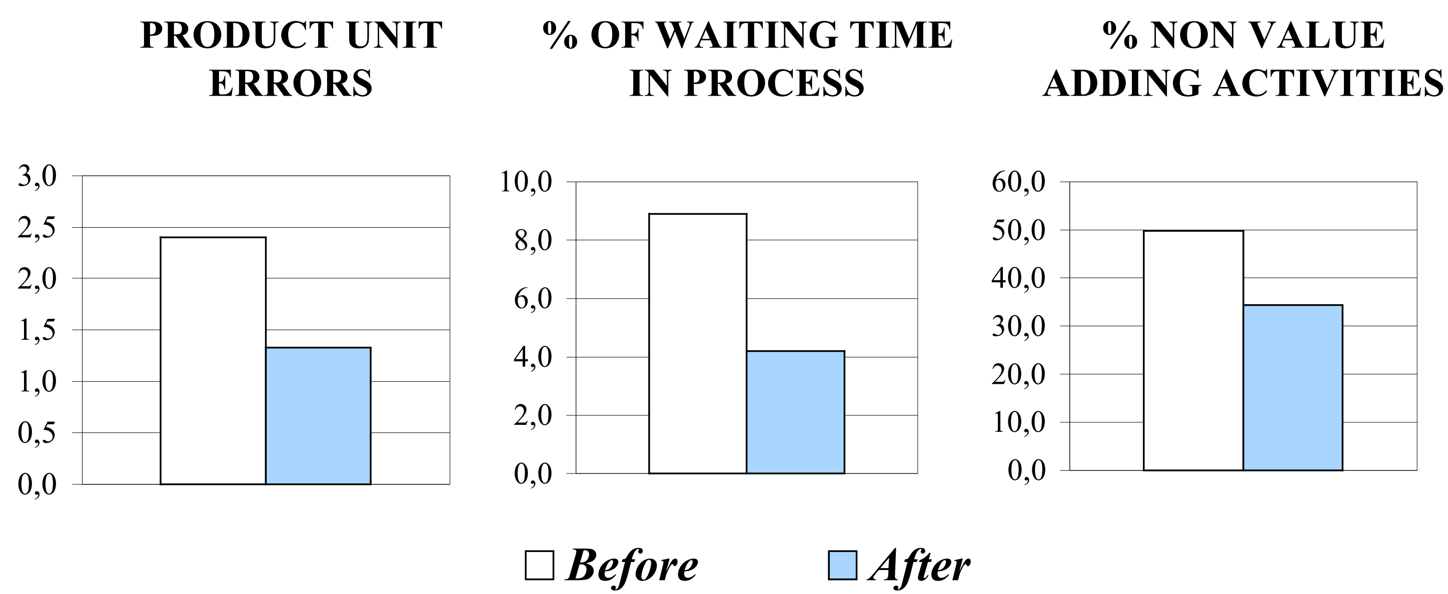
Lean Project Delivery & Sustainability

Proposal: Sustainability in design can only be achieved through lean project delivery—what the American Institute of Architects is now calling “integrated practice”. The interdependence of properties and the innovation required in solving new problems demands integrated teams without physical or social constraints on collaboration.



Business Objectives of Project-Based Producers
Minimize Waste
Deliver the Project
Maximize Value
Reduce defective products
Make materials & information flow/ reduce cycle times
Get more from less
Deliver products that enable customers to better accomplish their purposes
Deliver products on time/Reduce cycle time variation
Improve supplier quality & on-time delivery
Improve the quality of intermediate products
Structure work for flow
Reduce inspection time
Reduce rework time
Control work for flow
Reduce processing times
Reduce inventories
Reduce time mtls & info spend being moved and not processed
Increase resource productivity
Reduce the cost of acquiring resources, mtls, & info
Reduce the cost of using mtls & info
Structure work for value generation
Understand, critique, & expand customer purposes
Increase system control (ability to realize purposes)
Minimize production disruptions
Respond rapidly to production disruptions
Reduce the no. of suppliers & engage in lean
Actively learn with suppliers from project to project
Require evidence of product compliance from suppliers
Improve design constructability
Use in-process inspection
Pay after inspection/ QA
Use commissioning
Minimize negative iteration in design
Type, size, & locate buffers to absorb variability
Make prod. rate = demand rate
Use continuous flow processes where possible
Layout for flow
Simplify site work to final assembly & testing
Make inspection unnecessary or automatic
Incorporate inspection into processing time
Do in-process inspection
ID & act on causes of defective work
Use Last Planner
Reduce variability
Reduce transfer batch sizes
Reduce setup times
Pull mtls & info when possible
Reduce process batches
Apply technology
Redesign products for less processing time
Reduce 'distances'
Increase movement speed
Reduce no. of moves
Increase resource utilization
Increase resource fruitfulness
Assign tasks where best done
Reduce transaction costs
Reduce purchase prices
Reduce material scrap
Reduce unneeded work space
Reduce 'emissions'
Align stakeholder interests
Organize in cross functional teams
Increase positive iteration
Use a collaborative project definition process
Use a set based strategy in design
Design for all life cycle stages
Inspect against purposes
Focus control on the complete system
Simplify the system
Increase system transparency
Reduce variability
Reduce variability
Structure for robustness
Detect disruptions quickly
React quickly

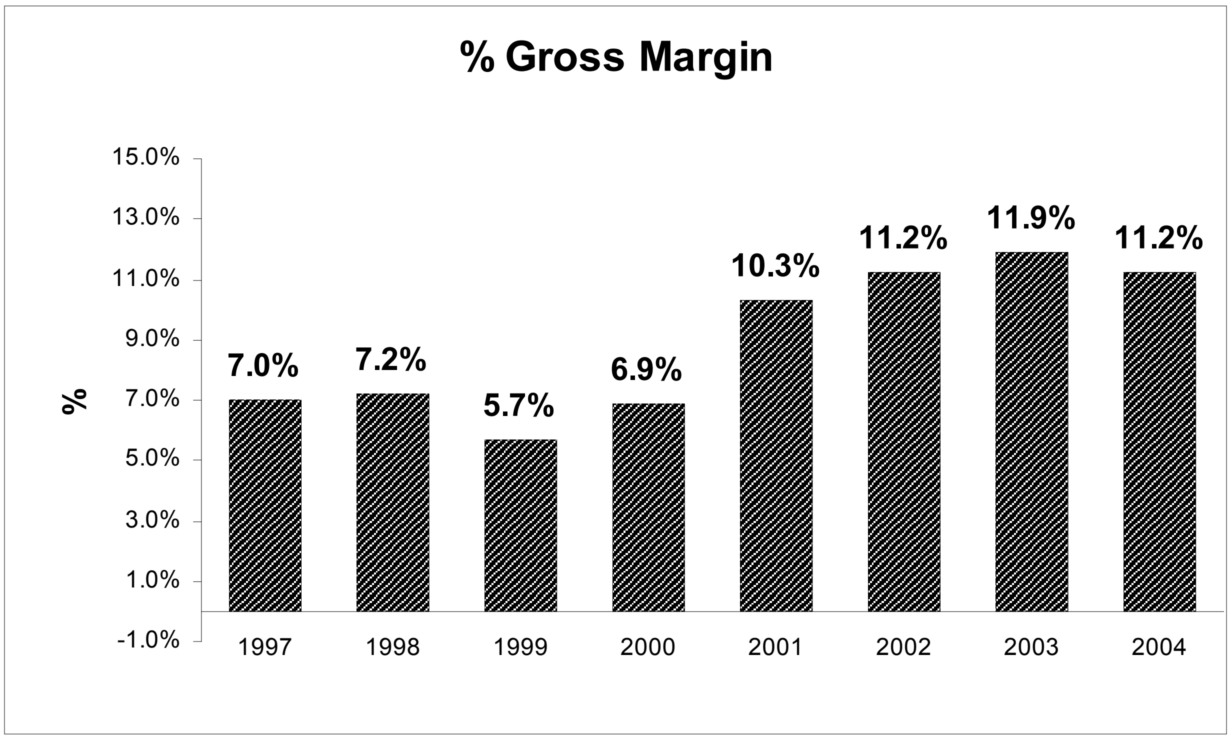
Waste reduction in a design office



44% Decrease **53% Reduction** **31% Decrease**

PRODUCTIVITY INCREASE OF 31%

Profitability Increase



What's the next step?

- Typical trajectory for builders is from the Last Planner® and reliable workflow into Design and Supply.
- Designers tend to start from Last Planner® and nD modeling.
- Use pilot projects to prove concept and to reveal both larger opportunities and organizational obstacles.
- Build a compelling narrative for change, get the team ready, assure first implementation is done right. Build on success.
- Urgency, Structure, Focus, Discipline, Training, Action and COACHING.

Implementation

- Start with Last Planner®™-moral equivalent in projects of 5S in shops.
- Get early wins.
- Encourage incremental development, but don't tolerate 'giving it a try'. Implacable leadership is a necessity.
- Players usually can't distinguish muscle from fat because of the lack of theory. Need guidance.

Transformation Matrix (Generic)

	Description	Who	Phases of Transformation: Team Ready	1st successful Completion	Team Entrenched	Enterprise Behavior
Tell Compelling Narrative	1. What's not working & what it will lead to. 2. What gives hope that is can get better & why (vision). 3. What I (& we) are already doing about it. 4. Invite their participation in this noble effort.	Key Staff Members ↓	Document vision (1 page) Communicate: @All Hands @Each training event @etc., etc.	Vision evolves as progress is made → Announce anticipation of new behavior	What is improved & what still needs help	All Staff Members -Speak of Success -Invite others to "take a look
Show Behavior	Examples & Constitutive Distinctions		-Simulations w/reflection -Clinic -Implement 1st runs (LPS, MSRP)	-Clinic -All levels of Implementation	Consistent demonstration of new behavior e.g:collaborate vs order	Demonstrate new behavior e.g: proactive constraint removal, reliable promising
Coach Behavior	- Practice Basics - Progression - Exceptions - Routine (Inside of Trust Between Parties)		External Coaching		Peer Coaching	-Ask different questions of performers -Engaged vs detached
Produce Alignment (Eliminate Barriers)	- Reconcile Disconnects Between New & Old Behavior - Mitigate Resistance - Measurement Conflicts		-Key people on board Influential people not negative	Request all Mgrs to learn how to make "lean" work	-Team is "seed corn" for expansion -Reconcile differences e.g: Controls -Fishbowl for leaders	-Change metrics e.g: profit speed
Continuously Improve	- Positive/Negative Feedback (more positive) - Appropriate to Level of Competence - Raise Bar While Expecting to go over more often.		E.g:: appropriate categories for variance & constraints	E.g: recording variances, estimating time	E.g: eliminate a variance, "Lean" the team (Kaizen)	

Taking the Initiative

- Owner Lead - BAA, Sutter Health
- Design/Builder - Neenan
- Joint Venture - IPD
- Designer Lead - Burt Hill; IDC
- General Contractor - Boldt, Linbeck, Messer
- Specialty - Enclos, Kinetics, Simpson, Southland
- Consultant - Strategic Project Solutions

What are your takeaways?

What questions have been provoked?

Agenda

- Start up
- Work Structuring/Production System Design
  - Airplane Simulation
  - Case Studies in Design of Fabrication Systems: Malling and SpanCrete
  - Case Studies in Design of Site Installation Systems: Brazil (Pereira)
  - Case Study in Design of Supply Systems: Hollow Metal Doors (Boldt)
- The Physics of Production-Work Flow
  - The Parade of Trades Simulation
- The Physics of Coordination
  - Workflow loop
- Production System Control using the Last Planner® System
  - Pull scheduling
  - Lookahead planning
  - Reliable promising
  - Learning
- More about Lean Project Delivery (if time available)
- Implementation/Organization Structuring
- Research directions
- Wrap up

Seminar Objectives

- Understand the theoretical basis of the Lean Project Delivery System.
- Understand its language, essential features, principles, tools and techniques.
- Make clear the primary differences between the Lean Project Delivery System and current practice.
- Encourage you to take action.