CMP831
Lean Construction Principles and Methods

Lean Construction Overview

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Module I
Traditional Construction Management

Module I will present:

• An overview of the construction industry
• The rise of construction management
• The state of the industry with respect to its management practices
• Essential features of contemporary construction management techniques
• The problems with current construction management techniques
Construction Projects

• The construction industry is characterized by:
  – Different Construction categories
  – Different workplace/workstations
  – Nature of sites (multi-employer/environment/clean!!!)
  – Physical work
  – Special trades
  – Teamwork (GC, Subs, Suppliers, A/E, Owner, Government)

• Construction projects in the US are broken down as follows:
  – Residential [30-50%]
  – Building Construction [35-40%]: (office buildings, banks, shopping centers, dealerships, sport complexes, hospitals, universities)
  – Engineered (heavy and highway) Construction [20-25%]: (highways, airports, harbors, tunnels, bridges, dams, pipelines, waterways, sewage plants)
  – Industrial [5-10%]: (processing plans, refineries, steel mills)
Construction Project Phases

- Four distinct and essential phases (Ahuja et al 1994):
  - **Conceive:**
    - Owner’s Need Statement
    - Establishment of General Requirements
    - Feasibility and Impact Studies
    - Conceptual Design
  - **Develop:**
    - Preliminary Design
    - Detailed Design
  - **Execute:**
    - Assign Construction Team
    - Procurement
    - Onsite Planning
    - Construction
    - Commissioning
  - **Finish:**
    - Commissioning
    - Training

- This is a linear view of a process that is inherently non-linear
• This is still a linear view of a process that is inherently non-linear.

Construction Management

• The increasing complexity of contractual relations and the construction process lead to the need for a professional who is responsible for the managing of the construction process. Typically referred to as the construction manager.
Construction Management is defined as the judicious allocation of resources to finish a project on time, at budget, and at desired quality (Sears and Clough 1994).

- This definition is a reflection of the famous triangle of tradeoffs between Time/Cost/Quality. A long running joke in the industry has been that you can only get two out of the three attributes.
Quality – Cost Tradeoffs

- Where did the T/Q/C tradeoffs come from?
  Well, from the graph below.
Time – Cost Tradeoffs

- Where did the T/Q/C tradeoffs come from? Well, from the graph below.

T/C guides planning/control
The roots of T/C, Q/C tradeoffs can be found in inventory management literature as far back as the ’20s. (Compare to graphs on previous two pages!)
Current State of Construction

Figure 1.2. Effects of low productivity in the construction industry. (Adrian & Adrian 1995)
Current State

The 6th annual survey of construction owners by CMAA (2005) reveals:

• Between 40 and 50 percent of all construction projects are running behind schedule (same as previous years).
Current State

The 6th annual survey of construction owners by CMAA (2005) reveals:

• The biggest cost impacting construction today is that of inefficiencies built into the way projects are run and managed – not costs of raw materials like steel and concrete, or the cost of labor.
Current State

Survey (cont.):

• “Trust and integrity are required ingredients for improving communications and collaboration”
Current State

Survey (cont.):

• More than a third of owners said they felt their project controls were not adequate, citing project management and cost controls as areas most in need of improvement.
Current State

Survey (cont.):

• There is a clear trend among government and quasi-public owners to break out of the design-bid-build pattern and explore other options, judging these options on the basis of which best meets the needs of a specific project.
Owners top concerns (CMAA 2005):

- Trust and integrity in the construction process
- Coordination/Collaboration among team members
- Improved relationships between contractors, CM staff, designers, and final users
- A/E consciousness of the cost to build their designs
- Bringing contractors, subs, and suppliers on board during the design phase
- Scope control/communicating a clear work scope
- Providing drawings that are more complete to build the project
- Owner responsibility for the process
- Owner decision-making responsiveness
- Attaining good project definition
“Owners are beginning to see how their own approaches to construction can actually foster inefficiency and raise costs -- or, in contrast, how the right strategy can create the kind of collaborative and open working environment in which jobs are done quickly and done right”

CMAA Executive Director Bruce D’Agostino.
Construction Waste (CURT)

- Correction/Re-work
- Performing work out of sequence
- Waiting for design comments
- Inefficient construction methods
- Marshalling of materials on-site
- Redundant design/construction processes
- Lack of “JIT” construction practices
- Inefficient teamwork/communication
- Slowdown/stoppage in work processes
Wasted Time is Out of Control

Manufacturing

Productive Time

Waste 12%

Construction

Waste 57%

Productive Time

Source: Construction Industry Institute 2004
Traditional Project Delivery
Level of Common Understanding

- Pre-Construction Services
  - Architect Hired
  - Engineers Hired
  - CM/GC Hired
- Construction
  - Major Trades Hired

Common Understanding

Time

McDonough Holland & Allen PC
Attorneys At Law

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Design/Build
CM Agency
/At-Risk

Traditional Project Delivery
Level of **Common** Understanding

Adapted from:
Design/Build CM Agency /At-Risk

Adapted from:
McDonough Holland & Allen PC
Attorneys At Law
Management Levels in Construction

Adapted from Halpin and Woodhead (2000)

- **Organizational**
  - Company structure; Multiple project attributes

- **Project**
  - Project breakdown according to contract, specs, dwgs; cost; time; resource control
  - Activity status against budgeted cost/time; resources use

- **Activity**
  - Focus on day-to-day functions.
  - Choice of construction methods.
  - Decisions on activity sequencing.
  - Management of trade interactions

Today, CM focuses on this box!!!

Transformation Management
How do we manage projects now?

Focus on transformation activities

• Determine client requirements (including quality, time and budget limits) and design to meet them

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How do we manage projects now?
Focus on transformation activities

Cost estimates for activities are identified.

Conventional Cost principle

Cost + Profit = Price

Kentucky Center for Experiential Education 1998 / Shingo 1989 (adapted)
Using the estimating formula “Cost + Profit = Price” assumes that the whole is the sum of its parts! It also assumes that if we perform each part at the lowest cost, then the entire project will be performed at the lowest cost.

We know projects don’t necessarily get done at the lowest cost estimated or even bid.

We also know that the whole is definitely not the sum of its parts.
Conventional Cost principle

I gathered all the padded cost estimates from the liars and scoundrels. I'm ashamed to call co-workers.

That's okay. I usually ignore our cost estimates and make bidding proposals that I think will win.

I gather inaccurate data for a living. Luckily no one uses it.

Your glass is half full.

I need a description of your project and its projected cost.

That's impossible.

The project uncertainty principle says that if you understand a project, you won't know its cost, and vice versa.

You just made that up.

That doesn't make it wrong.
"Looks like Tommy's running over budget again..."
How do we manage projects now?
Focus on transformation activities

- Break project into activities, estimating duration and resource requirements for each activity and placing in a logical order with CPM
Can you explain why your project is behind schedule?

Yes. A schedule is an artificial device created without knowledge of the future.

Wild guesses are used as surrogates for knowledge.

Protect deadlines are tied to trade show dates instead of reality.

Then management cuts the budget until failure is assured.

I assume you called me here so you can apologize for your role in all this.

Would you like to hear how budgets are created?
“The schedule is not the plan. The schedule is simply one component of the Project Implementation Plan...The plan is revised and fine-tuned as we gain more understanding of the project and its details.”

Rainbows & Ratholes: Best practices for managing successful projects - by Dhanu Kothari (2006)

"Plans are nothing, planning is everything---Dwight D. Eisenhower "

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How do we manage projects now?
Focus on transformation activities

- **Assign** or **contract** each activity, give start notice and monitor safety, quality, time and cost standards. Act on negative variance from standards.

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How do we manage projects now?

Focus on transformation activities

- Coordinate work 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
Current Production Planning

Production is viewed only as a TRANSFORMATION of inputs to outputs

©Lean Construction Institute, 2001 (adapted)
Current project control focuses only on should vs. did; cost and schedule variances; recovery plans
Monitor work progress (production) and performance (productivity)

©Lean Construction Institute, 2001 (adapted)
Common Practice: Variance-Driven Control! (Earned Value)
Common Practice: Variance-Driven Control! (Earned Value)

By the time the variance is detected it may be too late for project to get back on track – Too sluggish of a response!!!

Reporting an aggregate schedule/cost variance overlooks the mini-failures going on (many negatives variances could be offset by one large positive variances)
Common Practice: ‘Can Do’ Attitude

Over-committing → Lack of Trust

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Current common practice is to make weekly production assignments (WILL) that may fall outside the ability of workers to perform (CAN). There is also instances when a commitment is made (WILL) for things that should not be done.
Construction work is a function of Cycle Time = Conversion + Handling + Inspection + Wait

- **Handling + Inspection + Wait** component considered part of doing the business...Addressed using Work Sampling / Productivity Studies.

- **1-5% Conversion**: Value adding
- **95-99%, Handling, Inspections, and Wait**: Non-Value adding; Waste

Common Practice: Sub-Optimizing!
Common Practice: Sub-Optimizing!

- Cycle Time = Conversion + Handling + Inspection + Wait
  - Focus has been on reducing conversion time using technology, equipment, automation, and to some extent modularization.
Why has focus been on reducing conversion time when the majority of the cycle time is waste?

“I’m sending you to a seminar to help you work harder and be more productive.”
WORK SAMPLING
(which is the way productivity is traditionally improved in construction assumes that construction operations are independent)
THE PROJECT is made of interdependent (interconnected) activities. Improving one process will do nothing for the throughput of the system if the entire system is not considered. You are as strong as your weakest link, and as fast as your slowest process.
Is the concrete ready or will this foundation be left exposed for a couple of days? Is that good or bad planning?
This was an example of a foundation pit poured with the wrong anchor rods and plate. Why? Because no one checked. Rework is not really an inherent part of construction. It’s self-inflicted in much of the cases, whether by design errors and omissions and/or contractor mistakes.
Essential Features of Current Practice

- Activity centered: Ignores the effect of workflow variation on performance
- Optimizing “performance” at the activity level to increase productivity or point speed
- Deviation-based control (tracking)
- Each party in the project protects its own “turf” (activities)
- Little learning; repetitive failures.
- Ignores the creation and delivery of value
- Exhibits the Punch List Syndrome

©Lean Construction Institute, 2001
Changing Paradigm – owners want more

HOW can the industry deliver the new attributes if it had trouble with the original triangle???

Industry Solutions

To counter problems caused by the shortfalls of current CM paradigm and to attempt giving owners more than Time/Cost/Quality, which weren’t consistently delivered, some companies started to consider solutions (workarounds):

- Value-engineering
- Design-build
- Partnering
- TQM /QFD
- Constructability
- Safety
- IT
- Productivity Improvement
- Computer Simulation
Industry Solutions

• Increased involvement of contractors and suppliers through design/build and partnerships – doesn’t work well
• Constructability is simply a reaction to a design and not a process where the design is INFORMED by the constructor
• Standardization of the recipe where it should have been standardization of the ingredients only

All these attempts are palliatives directed at fragmentation and contractual issues…..Still fail to consider entire system – sub-optimization is the result…..
Industry Solutions

• Use of multi-skilled teams to decouple dependence between activities
• Industrialization (fails because of sub-optimization)
• IT (fails as we are merely transferring wrong info faster)
• Computer simulations; celebrates the incorporation of variability in time and cost estimates without trying to remove this biggest source of waste and substandard performance.

All these attempts are palliatives directed at fragmentation and contractual issues…..Still fail to consider entire system – sub-optimization is the result….
Imagine an automobile assembly line where each step along the line is undertaken by a different company with its own financial interest and separate labor union!...Present [construction] practice is impossible. The client asks an architect to design something specifically for him. In making drawings the architect will specify various components out of catalogues. He is nearly always restricted to elements that are already manufactured. Then the contractor, who has usually had nothing to do with the design process, examines the drawings and makes his bid. Industry supplies raw materials and components and has little contact with the contractor. The various building material manufacturers make their components totally independent of each other...It is an **absurd Industry!**

Moshe Safdie
Module II
Lean Construction Management

– Module II will present:
  • An introduction to Lean Construction Management
What type of production is construction?

- Fixed-position manufacturing (whole assembled from parts; workers complete processes on a “stationary” product)
- Final product is “rooted” in place (uncertainties and customer involvement)
- Directives- Driven

Ballard and Howell (1997)
Production Theories

• What production Theory does construction follow?

  – Are there production theories?
    • Even if yes, theories are for academics only because a theory seeks the truth but compromises usefulness!! (Very incorrect statement)

  – A theory is a statement that describes and explains observations in real world and allows us to predict and control the observed system

  – “There is nothing more practical than a good theory” - Gregory Howell, co-Founder of LCI……..
Production Theories

Bertelsen and Koskela 2002

• Conversion/Transformation View
  – **Concept:** Convert/transform inputs to outputs
  – **Principles:** Getting production realized efficiently; Decompose the production task, and minimize the costs of all decomposed tasks;
  – **Methods:** WBS, MRP, OBS
  – **Practical contribution:** Taking care of what has to be done
  ✓ Essentially an “Activity Management” philosophy
Production Paradigms/Theories

Bertelsen and Koskela 2002

• Flow view

  – **Concept:** Flow of material is composed of transformation, inspection, moving and waiting
  – **Principles:** Elimination of *WASTE* (non-value-adding activities) by compressing lead times, reducing variability, increasing transparency and flexibility
  – **Methods:** Continuous flow, pull production control, JIT, continuous improvement
  – **Practical contribution:** Taking care that what is unnecessary is done as little as possible

✓ Essentially a “Flow (WASTE) Management” philosophy
Production Paradigms/Theories

Bertelsen and Koskela 2002

• Value Generation View
  – **Concept:** Production fulfils requirements of a customer; creation and delivery of value
  – **Principles:** Elimination of value loss (realized outcome versus best possible) by ensuring customer needs and wants are captured & **challenged**
  – **Methods:** QFD, AHP, DCM
  – **Practical contribution:** Taking care that customer requirements are met in the best possible manner
  ✓ Essentially a “Value management” Philosophy
Today’s Construction Management Focus. The other theories of project and management need to be considered. That’s what Lean Construction advocates and encompasses.

Lean Construction

Project management practiced today gives us strategy – akin to the process of controlling the mainsail and rudders).

What is missing is the production management process – akin to the process of trimming the front jib sail and balancing the boat).

*Lean Construction achieves both and promotes continuous improvement through change!!*
Future Construction Production

- Today’s Construction is guided and influenced by the “Activity Management” (Transformation View)
- We need to consider Flow (WASTE) Management and Value Management
- Lean Construction considers all three and more
WE PRACTICE:

PROJECT PLANNING AND CONTROL; BUT WE ALSO NEED:

PRODUCTION PLANNING AND CONTROL
What is “LEAN” Construction?

“A way to design production systems to minimize waste of materials, time, and effort in order to generate the maximum possible amount of value.”

What is “LEAN” Construction?

- Wlabridge Aldinger defines LC through its features and requirements...LC is a process that:
  - Reduces Waste
  - Saves Money and Reduces Cost
  - Creates Higher Quality
  - Creates Flexible Delivery Systems to Match Owner Requirements
  - Creates Stable Schedules
  - Reliable Material Deliveries and Reliable Workforce
  - Promotes Employee Participation, Which Leads to Satisfaction
  - Improves Customer Satisfaction
  - Requires a Cultural Change.

(http://www.walbridge.com/lean/index.htm)
Waste vs. Value

- Waste is usually what reduces value for the performer.

- Value for the client is produced by their assessment of the deliverable when it is delivered.
“LEAN” Construction allows you to arrive at all your goals without a trade-off.

Lean Construction advocates are working on figuring out the mechanism and means to achieve all sides of the cube without having to settle for one or two faces at a time.
What is Lean?

- Continuous Improvement
- People Involvement
- Standardization
- Owners
- Short Lead Time
- Built-In-Quality / Eliminate Waste
Transformation-Flow-Value
Theory of Production

Craft Production
Mass Production
Lean Production
Value Management

Social System

Lean Construction

autonomous agent

Management Theory

PLANNING
Management-as-Planning
Management-as-organizing

CONTROL
Thermostat model
Scientific experimentation model

EXEUCUTION
Classical Communication theory
Language/action perspective
How is “LEAN” Construction different?

- Lean Construction supplements traditional construction management approaches with:
  - two critical and necessary dimensions for successful capital project delivery by requiring the deliberate consideration of material and information flow and value generation in a production system.
  - a different management (planning-execution-control) paradigm
System States based on quality conformance and existence of common and special cause variances

Adapted from David J. Anderson posting at http://www.agilemanagement.net/Articles/Weblog/FeaturedBlogEntries/QualityasaCompetitiveWeap.html

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System States based on quality conformance and existence of common and special cause variances

- Change (improve process) or
- Relax standard for conformance

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Partial Lean Construction (cycle time reductions only)
Module III
Lean Construction Management

– Module III will present:
  • Lean Construction Value
    – A Management BY Values approach
Typical Value Definitions

• “Value” – fitness for use; comes from quality literature

• “Value” – performance relative to cost; value engineering definition….reducing cost will give better value
  – Value Engineering is improving the "Value" by examining the ratio of value function to its cost.
Relationship Between Customer Satisfaction and the Fulfillment of Required Features

**Attractive**
These features have the greatest impact on satisfaction, and the fulfillment of these requirements leads to more than proportional satisfaction.

**One-dimensional**
Customer satisfaction is directly proportional to the degree of improvement provided.

**Must-have**
If the product does not have these specific features, the customer will be dissatisfied.

Typical Value Definitions

• “Value” results from the combination of such things as design, engineering, factory performance, vendor selection & management, and marketing, and depends on the competitive environment, and the world economy.

• In a capitalist economy, “value” can only be measured at points where real money (not internal work orders) changes hands.
‘Lean’ Value

“A capability provided to a customer at the right time at an appropriate price, as defined in each case by the customer.”

*Lean Thinking*, (Womack and Jones 1996)
Deming’s Last Interview

The customer invents nothing. The customer does not contribute to design of product or the design of the service. He takes what he gets. Customer expectations? Nonsense. No customer ever asked for the electric light, the pneumatic tire, the VCR, or the CD. All customer expectations are only what you and your competitor have led him to expect. He knows nothing else.

• Management of Value is similar to Value Engineering

• Management of Value ≠ Value Management

• Value management is the practice of managing performance by focusing on those activities that add value, so it's a mean to an end - the value the client desires.
Value in Construction

• Value is generated through the interaction between customer and supplier, wherein the customers provide the requirements and the supplier delivers it.

• **Principle:** Elimination of value loss (realized outcome versus best possible) by ensuring customer needs and wants are captured & challenged (QFD, AHP, DCM)

• **Practical contribution:** Taking care that customer requirements are met in the best possible manner
Value in Construction

• Value is generated when (LCI 2001):

  – Customer capabilities are expanded, creating new needs and purposes.

  – The facility better fulfills the purposes of customers/producers and demands of other stakeholders

  – (not just fitness for use or performance relative to cost)
Value in Construction

• Value is described as:
  – “Conceptualization of production (from value viewpoint): As a process where value for the customer is created through fulfillment of his requirements.” Bertelsen & Koskela (2002)
  – “…the construction process generates the value wanted by the client.” Bertelsen & Koskela (2002)
  – “Value is generated through a process of negotiation between customer ends and means.” Ballard & Howell (1998)

Value mainly as both utility and market value, i.e. product value in Lean Construction.
Value in Construction

- Value is a temporally changing subjective quality that is determined by the client – the client will have different values as the facility is evolving and even after it’s delivered and occupied.
- In general value from the client standpoint cannot be separated from the utility the client derives from it.
- Maximizing value means maximizing the utility the client derives from the facility they requested to be built. Utility is maximized through a management BY values approach which simultaneously considers product and process value management.
- Lean Construction can minimize the differential between desired value and realized value.
Value in Construction

• “Value is what the customer says it is” – Greg Howell – co-founder Lean Construction Institute

• “Value is in the eye of the beholder”

• “The Client wants to know how you will add value to his project” President of Parsons Brinckerhoff Construction Services…Controlling time, cost, and quality is not enough…ENR Magazine, ….December 2, 2002
Leinonen & Huovila (2000) mentions three different kinds of values; exchange (market) value, use (utility) value and esteem value.
Value in Construction

“VALUE-BASED MANAGEMENT IN THE SUPPLY CHAIN OF CONSTRUCTION PROJECTS” — IGLC12- 2004 - Søren Wandahl and Erik Bejder
Value in Construction

“VALUE-BASED MANAGEMENT IN THE SUPPLY CHAIN OF CONSTRUCTION PROJECTS” – IGLC12- 2004 - Søren Wandahl and Erik Bejder
• In Lean Construction, value is not attained at the expense of the product. The process of delivery can be changed and managed in a better way to arrive at the desired value.
Module IV
Lean Construction Management

– Module IV will present:
  • Lean Project Delivery System
    – Lean Construction Design
      » Target Costing
    – Lean Construction Supply
    – Lean Construction Assembly
    – Lean Use
Lean Project Delivery System

Ballard (2000); Adapted by T. Abdelhamid

Lean Design

Lean Assembly

Lean Supply

Work Structuring
Production Control

Purposes
Design Criteria
Design Concepts
Process Design
Product Design
Detailed Engn.
Fab. Logistics
Installation
Commissioning
Alteration Decomm.
Operation/ Maintenance

Project Definition

USE

KNOW WHAT THE OWNER REALLY WANTS

JIT, Modularize, Standardize, industrialize...

Product and Process; Suppliers Design, strategic alliances with suppliers

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Lean Project Delivery System

We will discuss the components: Project Definition, Lean Design, Lean supply, Lean Assembly, and Use.

Purposes

- Design Criteria
- Design Concepts
- Product Design
- Process Design

Installation

- Fab. Logistics
- Detailed Engn.

Lean Assembly

- Operation Maintenance
- Alteration Decomm.

Lean Design

- Commissioning
- Installation

Lean Supply

- KNOW WHAT THE OWNER REALLY WANTS

USE

- Product and Process; Suppliers Design, strategic alliances with suppliers
- JIT, Modularize Standardize, industrialize...

Ballard (2000); Adapted by T. Abdelhamid

KNOW WHAT THE OWNER REALLY WANTS

Product and Process; Suppliers Design, strategic alliances with suppliers

JIT, Modularize Standardize, industrialize...

Product and Process; Suppliers Design, strategic alliances with suppliers

Ballard (2000); Adapted by T. Abdelhamid
Project Definition

• Determining Purposes
• “Understand the client(s) business case.
• Understand user needs (customer profiling).
• Identify other stakeholders and their demands.
• Determine local conditions.
• Determine applicable codes, standards, & laws
Design Criteria for Product and Process

Voice of the Client

"I don't want people to be disturbed by sounds other than those from the stage."

"We're going to operate this facility, so we need to keep energy costs low."

"We're in a race with a competitor. We think we're ahead, but don't know how much."

Voice of the Designer

"Design to a decibel level of 17."

"Select HVAC equipment for low energy consumption."

"Accelerate project delivery within the bounds of safety, quality, and spending limits."
Designing vs Making

Designing
• Produces the recipe
• Quality is realization of purpose
• Variability of outcomes is desirable
• Iteration can generate value

Making
• Prepares the meal
• Quality is conformance to requirements
• Variability of outcomes is not desirable
• Iteration (rework) generates waste

Construction is both!!!!!! Why keep these separate?
Waste in Design
Needless (Negative) Iterations

## 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 look ahead period  
| * Measure PPC  
| * Identify and act on reasons for plan failure |
| Use technologies that facilitate lean design | * Shared geometry; single model  
| * Web based interface |
Mike Neville, Ghafari Associates
Lean 3D Driven Fabrication Processes (HVAC)

Fully coordinated HVAC model with steel and other mechanical/electrical/plumbing systems
Installation drawings generated directly from 3D Model.
Direct interface from fully coordinated 3D model to CNC machines
Fabrication occurs in controlled Offsite shop

RESULTS:
“Just in Time” delivery & installation without field changes
Potential to reduce raw materials by up to 20%
Schedule reduction
Mike Neville, Ghafari Associates

3D Model Integration

Screen Capture with Annotation with Automated Collision Detection

Allowed Immediate Subcontractor Coordination & Resolution
Integrated Project Delivery
Level of Common Understanding
Target Costing

Lean Construction Institute
Project Delivery Forum
April 22 – 23, 2004
Designing for X

- Cost
- Buildability
- Assembly
- Durability
- Flexibility
- Sustainability
- Etc.
DfX Challenges

1. How to incorporate the relevant specialists in the design process, both as regards knitting organizations together through contracts and effective processes for collaborative design
2. How to make tradeoff decisions between the characteristics
3. How to drive design decision making to the targets.
Designing to Target Cost…

- requires a fundamental shift in thinking from 'expected costs' to 'target costs'.
- strives to reduce the waste and rework in the Design/Estimate/Redesign cycle.
- necessarily involves cross functional teams. No one person has all the knowledge.
- cries out for an integrated product/process /cost model.
What is the role of Target Costing?
Value management or Flow management or both!

Target costing is not the same as GMP. The latter is the sum of all the bids plus contingency. The former is a different view all together.
3 applications of target costing in construction

1. A client has a limited amount of money to spend and wants to spend all of it to the extent that value adding investment opportunities can be found.

2. A provider needs or wants to commit to a fixed price or guaranteed maximum price.

3. A developer targets a production cost to generate a desirable profit margin, assuming an achievable sales price; i.e., the traditional product development application.
The Cardinal Rule of Target Costing

“The target cost of a facility can never be exceeded.”
Lean Design and Target Costing

- An investment decision making process and disciplined approach to project financial management.

- Target Costing starts at Project Definition or very early in the design phase.

- The process continues throughout all phases of facility delivery.

- *The budget becomes an influence on design and decision-making, rather than an outcome of design.*
Applying the Cardinal Rule

- 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.
Target Costing
3 Basic Steps

- Establish the *allowable target cost* as defined by customer including all indirect cost and profit.

- Establish the *achievable target cost* by subtracting the profit margin and cost reduction potential throughout value stream.

- Decompose the project level target cost down to *component level target cost* so the purchase price of components can be determined.
The Process

- Document and understand the customer’s expectations regarding cost, function and quality.

- Align specific programming needs and financial constraints.

- Establish the interdisciplinary Target Cost Team
  - Architects, Engineers, Facility Users, Estimators, Specialty Contractors and Suppliers, Project Manager
  - Co-locate. The first jobsite in a project is in the design office.
The Process Continued:

- Start the “Reverse Estimating” process
- Establish the overall target cost.
- Divide the overall target cost into component target costs
  - Building Component (site, substructure, superstructure, enclosure, finishes, FFE, MEPFP)
  - Functional Program
  - Phase
The Process Continued:

- Simultaneously design the product and the process.
- Work through a series of large group meetings and smaller component workshops.
- Use set based design, sets of solutions that satisfy cost, function and quality, advanced to the last responsible moment – *Pulling information in small batches.*
The project team is responsible to promptly inform the Customer of any cost impact when added scope increases the cost of the facility.

The cardinal rule of target costing can only be broken when the Customer’s decision makers agree to increase cost resulting from changes or additional scope that increase the value of the facility.
The Process Continued:

- Apply Value Analysis techniques.
  - Function Analysis, Life Cycle Costing, QFD

- Negotiate budget allocations between teams as design and budget information evolves.

- Maintain the Component Teams to monitor and manage the Target Cost throughout the life of the project.
Using Value Engineering as a Target Costing Tool

- Systematic and interdisciplinary
- Examination of a project and project components in terms of function and worth.
- Structured methodology
- Encourages analysis and creativity
- Develops sets of solutions
- Develops highest value solution based on functionality and cost.
Value Engineering
5 Basic Steps

- **What is it?** The first question focuses the analysis. When associated with target costing the analysis is on major functions or systems, and the components and subcomponents of a project.

- **What does it do?** The second question defines function. Function analysis is at the heart of value engineering and is required for determining value. An important product of function analysis is the improvement in understanding of scope that occurs among the study team members.

- **What does it cost?** The third question deals with the cost of functions. The purpose is to identify those functions where value is low compared to cost. These items are prime for value engineering.

- **What else will do the job?** The fourth question requires creativity and innovation to advance sets of alternative solutions.

- **What does it cost?** The fifth question is similar to the third but focuses the on the highest value solution in terms of function and cost. Cost is determined in terms of initial capital cost and life cycle cost.
The Lean Design Process

- Understanding the customer’s expectations regarding cost, function and quality

- Co-located, Multidisciplinary Target Cost Teams
  Designers, Facility Users, Estimators, Specialty Contractors and Suppliers, Project Manager, Superintendent

- Targeting both Project Cost & Component Costs

- Applying Value Engineering
  Function Analysis, Life Cycle Costing, Quality Function Deployment

- Set Based Design
  Advancing sets of solutions to the last responsible moment

- Simultaneous design of Product and Process
  3D prototyping

- Detailed design by specialty contractors and vendors
Features and Benefits of Target Costing

- Scope of Work Document based on Quantity, Quality, and Cost
  
- Updated Target Cost Model for design and construction
  
- Commitment from the entire project team to design and build according to the scope and budget
  
- Clear translation of the Voice of the Customer into technical design, and ultimately to product delivery
  
- The basis of Financial Management and Investment Decision Making throughout the project

- The assurance of Lowest Product Cost and Highest Customer Value
Read This!!!

*Target Costing and Value Engineering*
Robin Cooper and Regine Slagmulder
Productivity Press 1997
Lean Supply To Do’s

• Early applications of JIT in construction should focus on reducing on-site waste and operations variation by:
  1. Selecting location and size of material buffers / schedule buffers / surge piles (Use Computer Simulation)
  2. Creating alternative work for crews - plan buffers (Use Last Planner)

• Shift detailed engineering to fabricators and installers.
• Structure logistics so materials can be pulled to site in small batches.

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Map the Supply Chain

Extraction

Fabrication

Construction Site

Fabrication

Suppliers
Map the Supply Chain

- Extraction
- Fabrication
- Suppliers
- Construction Site
- Supermarket
Lean Supply

At some point move to complete off-site assembly
Lean Assembly To Do’s

• Standardize and industrialize
  – Standardize the ingredients, not the recipe

• Use 5S, poke-yoke

• Simplify site installation to final assembly and test

• “Flow where you can, Pull where you must”
  – Strive for one-touch material handling
  – Pull from off-site suppliers

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Lean Project Delivery System

Ballard (2000); Adapted by T. Abdelhamid

- MUCH WORK REMAINS
- FACILITIES MANAGEMENT AREA
Lean Project Delivery System - USE

Lean Project Delivery System - USE

– “Operating expenses represent over 95 percent of building life cycle costs, yet operations and maintenance personnel are usually the last to be consulted during programming and design” (NIBS 2003)

– When 1% of upfront cost are spent, 70% of the life cycle cost of a bldg may have been committed (Romm 1994)

Module IV
Lean Construction Management

– Module IV will present:

• Lean Construction and Workflow Reliability
  – Work Structuring (project and production planning)
  – Production Control
Lean Project Delivery System

Ballard (2000); Adapted by T. Abdelhamid

Product and Process; Suppliers Design, strategic alliances with suppliers

JIT, Modularize Standardize, industrialize...

KNOW WHAT THE OWNER REALLY WANTS

Know what the owner really wants

Product and Design, strategic alliances with suppliers

Lean Assembly

Lean Design

Lean Supply

Work Structuring Production Control

Use

Project Definition

Lean Design

Lean Assembly

Lean Supply

Detailed Engn.

Detailed Engn.

Detailed Engn.

Detailed Engn.

Detailed Engn.

Detailed Engn.

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Detailed Engn.

Detailed Engn.
Lean Project Delivery System

We will first discuss the “heart” of the LPDS: Work Structuring and Production Control.
LEAN CONSTRUCTION

IMPROVE WORKFLOW RELIABILITY ON YOUR SITE BY THINKING THROUGH PRODUCTION PROCESS DURING PRODUCT DESIGN!!!!!!!!!
Production Planning and Control in Lean Construction

• Production management (planning and control) enables better performance at the system level by exposing work flow issues (waste in production, design and supply) at the task levels.

• Improve work flow using the tools we have in the lean toolbox or by developing new ones.
A project isn’t a house of cards. [But] the current planning system cannot predict the work that will be completed to hand off criteria about 50% of the time. And projects still get done on schedule – Greg Howell (2004)
We need more reliable workflow at the lowest levels of work to eliminate resource increases towards the last portions of work. We need a different kind of production management (planning and control).
RELIABLE WORKFLOW AT THESE LEVELS ACHIEVED USING

LEAN PRODUCTION MANAGEMENT

Production Planning = Lean Work Structuring (LWS)  
Production Control = Last Planner System (LPS)
Production Management

• Improving Hand-off BETWEEN Production Units

  – PLAN FOR THE PROJECT USING WORK STRUCTURING

  – PLAN FOR PRODUCTION USING THE LAST PLANNER SYSTEM
    • Lookahead to identify constrains and increase reliability of commitments
    • Master and Phase (Pull) Scheduling
    • Lookahead Scheduling
    • Weekly Work Planning

(Unless commitments are made, there are only promises and hopes but no plans….Peter Drucker)
LEAN PROJECT AND PRODUCTION PLANNING

LEAN WORK STRUCTURING (LWS)
Lean Work Structuring

Work structuring develops and aligns the project’s process design with engineering design, supply chain capability, resource allocation strategies, and assembly efforts.

*Work structuring is production system design all the way down.*

• Each “chunk” of work is designed 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.
Lean Work Structuring

THINKING PRODUCTION (FLOW) DURING DESIGN AND PROJECT PLANNING!!!!!!!!!

FLOW

Waste - Muda

Variability - Mura

Overburden - Muri
Work Structuring: Master & Phase Schedules

Project Objectives → Work Structuring → Master and Phase Schedules

Information → Work Structuring

Can → The Last Planner → WILL

Inputs → Production → DID
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 Tools

- Pull Scheduling (to create Master/Phase)
# Master Schedule-1

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<thead>
<tr>
<th>Act ID</th>
<th>Description</th>
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<td>J</td>
<td>F</td>
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<td>Submit Proposal to DFD</td>
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<td></td>
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<tr>
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<td>DFD Authorization to Proceed</td>
<td>10d</td>
<td></td>
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<td>1030</td>
<td>Site Permit Review</td>
<td>30d</td>
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<td></td>
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<td>Prisoner Housing Permit Review</td>
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<td></td>
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<td>Design Phase</td>
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<td></td>
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<td></td>
<td></td>
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<td>1080</td>
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<td>25d</td>
<td></td>
<td></td>
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<td></td>
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<td>1105</td>
<td>MEP - Building Underground</td>
<td>20d</td>
<td></td>
<td></td>
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<tr>
<td>1085</td>
<td>Footings &amp; Foundation Package</td>
<td>30d</td>
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<tr>
<td>1115</td>
<td>MEP - Structural</td>
<td>20d</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>1090</td>
<td>Building - Structural &amp; Enclosure</td>
<td>40d</td>
<td></td>
<td></td>
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<td></td>
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<tr>
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<td>50d</td>
<td></td>
<td></td>
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<td>Site Development &amp; Utilities Bid Package</td>
<td>20d</td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>1250</td>
<td>Footing &amp; Foundation Bid Package</td>
<td>20d</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>1270</td>
<td>Building Enclosure Bid Package</td>
<td>20d</td>
<td></td>
<td></td>
<td></td>
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<td>1260</td>
<td>MEP Bid Package</td>
<td>20d</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1470</td>
<td>Building Finishes Bid Package</td>
<td>20d</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Purposes 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.

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Phase Scheduling: Purposes and Actions
Phase Scheduling: Purposes and Actions

• 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.
Entry Rules

• Rule 1: Allow activities to remain in the Master/Phase schedule unless positive knowledge exists that it should not or cannot be executed when scheduled.
Work Structuring Tools

- Value Stream Mapping / First-Run Studies (Before not During construction)

- Value Stream Mapping / First-Run Studies --still useful during construction

Waste - Muda
Variability - Mura
Overburden - Muri
Work Structuring Tools

- Construction Operations Simulation (how do you use it in a Lean context?)

  • Identify the characteristics of the operation
  • The bottlenecks but not to just have a utilization based improvement in the process…For example, increasing the number of loaders because the haulers are waiting or speeding up the loading. We have to look at the non-processing component of the cycle time (handling, wait, and inspection). Redesign the process to be more product based.
  • We also want to be careful not to contribute to overproduction.
  • Do not celebrate the inclusion of variability. We should try to remove the variability using Kaizen or Kaikaku and tools such as VSM, JIT, LastPlanner,
LEAN PRODUCTION CONTROL

The LAST PLANNER SYSTEM®

To manage a system effectively, you might focus on the interactions of the parts rather than their behavior taken separately. - Russell L. Ackoff
Workflow Variation

Workflow variability is a manifestation of operation \((Production \ unit)\) performance (cycle time) variability, i.e., the predecessor releasing work erratically to the successor!
Last Planner System of Production Control

- LPS is a production/workflow control system designed to:
  - Empower front-line personnel to make decision about what work to commit to;
  - Improve workflow by ensuring that future work is READY!! Look-ahead process: a pull process!!
  - Tracks PPC (Percent Plan Complete) as a measure of production system variability
Production Planning and Control

The Last Planner System

- Project Objectives
- Information
- Planning the Work
- Should vs. Did

Making Work Ready

Can

The Last Planner Phase II [work we KNOW can be done]

WILL

PPC = DIDs ÷ WILLS

Inputs

Production

SHOULD

CAN

WILL

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LAST PLANNER SYSTEM

Design Criteria

Work Structuring

Information

Master & Phase Schedule

Selecting, sequencing, & sizing work we think can be done

SHOULD

Current status & forecasts

Lookahead

CAN

Workable Backlog

Selecting, sequencing, & sizing work we know can be done

Will

Weekly Work Plans

Resources

Production

Completed Work

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LAST PLANNER SYSTEM

Design Criteria

Work Structuring

Master & Phase Schedule

SHOULD

Information

Selecting, sequencing, & sizing work we think can be done

CAN

Current status & forecasts

Lookahead

SHOULD

Selecting, sequencing, & sizing work we know can be done

CAN

Make work ready by screening, pulling, & FRS

Workable Backlog

SHOULD

Work Plans

SHOULD

Weekly Work Plans

Information

Selecting, sequencing, & sizing work we know can be done

Information

Current status & forecasts

Lookahead

SHOULD

Selecting, sequencing, & sizing work we think can be done

Information

Make work ready by screening, pulling, & FRS

Workable Backlog

SHOULD

Weekly Work Plans

Resources

Production

Completed Work

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## LOOKAHEAD SCHEDULE

<table>
<thead>
<tr>
<th>No.</th>
<th>Activity</th>
<th>Responsible Party</th>
<th>Comments / Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Build mock-up of room 11</td>
<td>Boldt</td>
<td>Millwork &amp; mirror</td>
</tr>
<tr>
<td>1</td>
<td>✔ Microscope vibration study</td>
<td>SLMC/STS</td>
<td>CD’s will be issued prior to this info; Isolation system will come as addendum</td>
</tr>
<tr>
<td>1</td>
<td>Bid &amp; award bid pack 3</td>
<td>Boldt</td>
<td>Review with Brad</td>
</tr>
<tr>
<td>1</td>
<td>Submit-review-approve roofing shopdrawings</td>
<td>Langer</td>
<td>Additional submittals required</td>
</tr>
<tr>
<td>1</td>
<td>Release updated construction documents</td>
<td>ARC</td>
<td>Coordinate with Ring &amp; Du</td>
</tr>
<tr>
<td>1</td>
<td>Demolition</td>
<td>Boldt</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Pour roof</td>
<td>Boldt</td>
<td>x</td>
</tr>
<tr>
<td>1</td>
<td>Expedite stone production</td>
<td>BDI</td>
<td>Stone was ordered 10-19-00</td>
</tr>
<tr>
<td>1</td>
<td>✔ Steel Shops: Curtainwall Support</td>
<td>Duwe</td>
<td>Klein Dickert will coordinate with Mike D</td>
</tr>
<tr>
<td>1</td>
<td>Roof detailing</td>
<td>Duwe</td>
<td>x</td>
</tr>
<tr>
<td>1</td>
<td>Phase 3 Millwork Shop Drawings</td>
<td>Precision</td>
<td>5-6 week lead time - Ordered 10-19-00</td>
</tr>
<tr>
<td>1</td>
<td>✔ Fabricate louvers</td>
<td>Air Flow</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>✔ Fabricate auto entrance doors</td>
<td>Besam</td>
<td>Shipping 11-3; Besam header to Dickert</td>
</tr>
<tr>
<td>1</td>
<td>✔ Fabricate curtainwall</td>
<td>Klein Dickert</td>
<td>Waiting for framing materials-by October</td>
</tr>
<tr>
<td>2</td>
<td>✔ Mock-up review</td>
<td>SLMC</td>
<td>Millwork; Mirror</td>
</tr>
<tr>
<td>2</td>
<td>✔ Masonry Work</td>
<td>BDI</td>
<td>Roger needs to confirm if brick is in</td>
</tr>
<tr>
<td>2</td>
<td>✔ Penthouse framing &amp; decking</td>
<td>Duwe</td>
<td>Boldt to confirm placement of AHU’s</td>
</tr>
<tr>
<td>2</td>
<td>✔ Bid Pack 3 Submittals</td>
<td>TBD</td>
<td>Award contracts</td>
</tr>
<tr>
<td>2</td>
<td>✔ Start work on patient rooms 3847 -49</td>
<td>TBD</td>
<td>Need to coordinate with Jan Keepers</td>
</tr>
</tbody>
</table>

### 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
- Review room numbering
  - ARC/Lukes
Entry Rules

• Rule 2: Allow activities to remain in the lookahead window only if the planner is confident that it can be made ready for execution when scheduled. (Screening)
Screening and Constraints

- Activities are made ready to be assigned by removing constraints.
- Screening is the process of analyzing the activities for constraints and evaluating if they can be removed in time for the planned start.
To manage a system effectively, you might focus on the interactions of the parts rather than their behavior taken separately. - Russell L. Ackoff

Mapping Language: Activity Definition Model

- Directives
- Prerequisite Work
- Process
- Resources
- Output
- Meets Criteria?
Task Explosion

Current CPM assumption

Layout → Excavate → Form

Layout Practices, Drawings → OK → Layout Complete → Excavate

Noise rules, Spoil location → OK → Hole ready → Form

Stakes Siteplan Benchmarks → Layout → Surveyor & Equipment

Equipment & Operator → Labor & Material

Actual

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Purposes 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
LAST PLANNER SYSTEM

Design Criteria

Information

Work Structuring

Master & Phase Schedule

Selecting, sequencing, & sizing work we think can be done

Information

Current status & forecasts

Make work ready by screening, pulling, & FRS

Lookahead

Selecting, sequencing, & sizing work we know can be done

Weekly Work Plans

Workable Backlog

Resources

Production

Completed Work

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Entry Rules

• Rule 3: Allow activities into weekly work plans only if all constraints have been removed. (Shielding)
Forming the Weekly Work Plan

Unless commitment is made, there are only promises and hopes... but no plans. - Peter Drucker
Required Work Attributes To Move From Should to Will

• Definition
• Soundness
• Sequence
• Size
• Learning

Work meeting these only goes to workable backlog

• Safe Safe Safe Safe Safe Safe Safe!!!!!!!
• Definition: Are assignments specific enough that the right type and amount of materials can be collected, work can be coordinated with other trades, and it is possible to tell at the end of the week if the assignment was completed?

• Soundness: Are all assignments sound, that is: Are all materials on hand? Is design complete? Is prerequisite work complete? Note: During the plan week, the foreman will have additional tasks to perform in order to make assignments ready to be executed, e.g., coordination with trades working in the same area, movement of materials to the point of installation, etc. However, the intent is to do whatever can be done to get the work ready before the week in which it is to be done.

• Sequence: Are assignments selected from those that are sound in the constructability order needed by the production unit itself and in the order needed by customer processes? Are additional, lower priority assignments identified as workable backlog, i.e., additional quality tasks available in case assignments fail or productivity exceeds expectations?

• Size: Are assignments sized to the productive capability of each crew or subcrew, while still being achievable within the plan period? Does the assignment produce work for the next production unit in the size and format required?

• Learning: Are assignments that are not completed within the week tracked and reasons identified?
### Weekly Planning

#### Weekly Work Plan

<table>
<thead>
<tr>
<th>Day</th>
<th>Make Ready Needs</th>
<th>Responsible Party</th>
<th>Assignment Description</th>
<th>Done?</th>
</tr>
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<td></td>
<td>Brad/STS</td>
<td>Remember the Five Criteria for Release of Assignments Defined - Sound - Proper Sequence - Right Size Able to Learn</td>
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<td></td>
<td>Dena/Brad</td>
<td>Award Bid Pack 3</td>
<td>x x x x x</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>Jose</td>
<td>Reissue construction documents</td>
<td>Coordinate with Ring &amp; DuChateau x x x x</td>
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<tr>
<td>2</td>
<td></td>
<td>Jarosz</td>
<td>Test Glycol Mains</td>
<td>x x x x x</td>
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<tr>
<td>3</td>
<td></td>
<td>Randy</td>
<td>Pour Roof</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>Roger Spahr</td>
<td>Confirm brick is ready</td>
<td>x</td>
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<tr>
<td>4</td>
<td></td>
<td>Rossi</td>
<td>Stone production</td>
<td>x x x x x</td>
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<td>5</td>
<td></td>
<td>Bob Brue</td>
<td>Complete roof framing</td>
<td>x x x</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>Bob Brue</td>
<td>Begin roof detailing</td>
<td>x x</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>Dick</td>
<td>Re-submit curtainwall support shops</td>
<td>x x x x</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>Jose</td>
<td>Issue penthouse curb ASK’s</td>
<td>x x x x</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>Precision</td>
<td>Submit Phase 2 millwork shops</td>
<td>x</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>Precision</td>
<td>Deliver mock-up millwork</td>
<td>x</td>
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<tr>
<td>7</td>
<td></td>
<td>Scott Harms</td>
<td>Submit additional roofing shops</td>
<td>x x</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>Jim L</td>
<td>Resubmit curtainwall shops</td>
<td>x</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>Jim L</td>
<td>Submit curtainwall Struct. Calcs</td>
<td>x</td>
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<tr>
<td>8</td>
<td></td>
<td>Jim L</td>
<td>Order Glass</td>
<td>ARC verbally confirm dimensions x</td>
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<tr>
<td>10</td>
<td></td>
<td>Air Flow</td>
<td>Fab. Louvers</td>
<td>x x x x x</td>
</tr>
</tbody>
</table>

**Project:** Same Day Surgery  
**Planner:** Dena Deibert  
**Week of 10/23/00**
LAST PLANNER SYSTEM

Design Criteria

Work Structuring

Master & Phase Schedule

Should

AMR

CAN

AA

Current status & forecasts

Information

Selecting, sequencing, & sizing work we think can be done

Lookahead

SHOULD

Weekly Work Plans

Selecting, sequencing, & sizing work we know can be done

Resources

Production

Completed Work

Action to prevent repetitive errors

Chart PPC & Reasons

Workable Backlog

Make work ready by screening, pulling, & FRS

Information

AA = assignments anticipated

AMR = Assignments Made-Ready

PPC = DIDs ÷ WILLS

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# Measuring PPC

**Project:** Same Day Surgery  
**Planner:** Dena Deibert  

<table>
<thead>
<tr>
<th>Assignment Description</th>
<th>Responsible Party</th>
<th>M</th>
<th>T</th>
<th>W</th>
<th>T</th>
<th>F</th>
<th>S</th>
<th>Y</th>
<th>N</th>
<th>Reasons For Variance / Comments</th>
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<tbody>
<tr>
<td>Review mock-up drywall dimensions</td>
<td>Randy</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>Y</td>
<td></td>
<td>Wardrobe dimensions changed</td>
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<tr>
<td>Review microscope vibration Study</td>
<td>David</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>N</td>
<td></td>
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<tr>
<td>Review bids - Bid Pack 3</td>
<td>Dena/ Brad</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>Y</td>
<td></td>
<td>Will award next week.</td>
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<tr>
<td>Review roofing shops</td>
<td>Jose’</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>Y</td>
<td></td>
<td>Week 1 of 2</td>
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<td>Complete concrete haunches</td>
<td>Randy</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td>Y</td>
<td></td>
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<tr>
<td>Release order on limestone</td>
<td>Dena</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Re-submit curtainwall support shops</td>
<td>Dick</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>N</td>
<td></td>
<td>Waiting for curtainwall shop drwg.</td>
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<tr>
<td>Roof framing: 75% complete</td>
<td>Bob Brue</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>Y</td>
<td></td>
<td></td>
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<tr>
<td>Submit Phase 2 Millwork Shops</td>
<td>Precision</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
<td>Y</td>
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<td>Week 2 of 3</td>
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<td>Fabricate mock-up millwork</td>
<td>Precision</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>Y</td>
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<tr>
<td>Re-submit curtainwall shops &amp; structural calcs</td>
<td>Jim Leicht</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>y</td>
<td>N</td>
<td></td>
<td>Middle of next week</td>
<td></td>
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<tr>
<td>Finalize review of louver shops</td>
<td>Tony/ David</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>Y</td>
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<tr>
<td>Review GL-1 and GL-2</td>
<td>ARC/Jim Leight</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>Y</td>
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# Reasons For Not Achieving 100% PPC - DRYWALL INSTALLERS

<table>
<thead>
<tr>
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<td>PPC</td>
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<td>62%</td>
<td>62%</td>
<td>35%</td>
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<td>Tasks Completed</td>
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<td>Coordination</td>
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<td>Engineering</td>
<td></td>
<td>1</td>
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<td>1</td>
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<tr>
<td>Owner Decision</td>
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<tr>
<td>Weather</td>
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<tr>
<td>Pre-Requisite</td>
<td></td>
<td>1</td>
<td>3</td>
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<td>Labor</td>
<td></td>
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<tr>
<td>Materials</td>
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<td>Contract</td>
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<td>Submittals</td>
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<tr>
<td>Equipment</td>
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<tr>
<td>RFI's</td>
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<tr>
<td>Space</td>
<td>3</td>
<td>1</td>
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<td>2</td>
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</table>
Percent of Planned Completed - DRYWALLERS

Week


% Completed

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# Variance Analysis - Reasons and Categorization

Diablo Construction Company  
East Lansing, Michigan

Project: Renovation of a 70 Yr. Old Fieldhouse  
Planner: Ken Gottschalk

<table>
<thead>
<tr>
<th>Last Planner Date</th>
<th>Reasons for Variance</th>
<th>Rain</th>
<th>Pre-Requisite</th>
<th>Design</th>
<th>Submittal</th>
<th>Other</th>
<th>Space</th>
<th>Equipment</th>
<th>Labor</th>
<th>Materials</th>
<th>Contract</th>
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</table>

Total Number of Variances

©Ken Gottschalk, 2002
Impact on Project PPC Per Category

<table>
<thead>
<tr>
<th>Reason</th>
<th>Number of Occurrences</th>
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<tbody>
<tr>
<td>Coordination</td>
<td>35</td>
</tr>
<tr>
<td>Labor</td>
<td>10</td>
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<tr>
<td>Space</td>
<td>5</td>
</tr>
<tr>
<td>Pre-Requisite</td>
<td>10</td>
</tr>
<tr>
<td>Owner Decision</td>
<td>5</td>
</tr>
<tr>
<td>RIs</td>
<td>5</td>
</tr>
<tr>
<td>Engineering</td>
<td>1</td>
</tr>
<tr>
<td>Materials</td>
<td>1</td>
</tr>
<tr>
<td>Equipment</td>
<td>1</td>
</tr>
<tr>
<td>Submittals</td>
<td>1</td>
</tr>
<tr>
<td>Weather</td>
<td>1</td>
</tr>
<tr>
<td>Contract / CO's</td>
<td>1</td>
</tr>
</tbody>
</table>
Categories Responsible for Incomplete PPC

- Weather
- Pre-Requisite
- Labor
- Materials
- Contract
- Submittals
- Equipment
- BFI's
- Space
- Coordination
- Engineering
- Owner Decision
LAST PLANNER SYSTEM

Selecting, sequencing, & sizing work we think can be done

Make work ready by screening, pulling, & FRS

Selecting, sequencing, & sizing work we know can be done

Information

Current status & forecasts

Design Criteria

Work Structuring

Master & Phase Schedule

SHOULD

AMR

CAN

�AA

Workable Backlog

Weekly Work Plans

Resources

Production

Completed Work

Chart PPC & Reasons

On Budget & Schedule?

Action to prevent Repetitive errors

On Budget & Schedule?

©Lean Construction Institute, 2001, T. Abdelhamid

AA = assignments anticipated

AMR = Assignments Made-Ready

PPC = DIDs ÷ WILLS

Tariq Abdelhamid- CMP831- Michigan State University 2008
Comparing the Results - Evolution of PPC

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Productivity Evolution

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Last Planner System Implemented; PPC increasing

Average Productivity before LPSI

Below Budget (Making $$)

Over Budget (Losing $$)

At Budget

MONTHS
Have Your Cake and Eat It Too: Reduce Cost, Reduce Cycle Time, Improve Quality

(1) – Reduce cycle time, maintain productivity
(2) – Increase productivity, maintain cycle time
(3) – Increase productivity, AND reduce cycle time

Which way should we try to go?
Last Planner for Workflow Reliability

Master & Phase Schedules

Lookahead Plan With Constraint Analysis

Planning System Measurement

Weekly Work Planning

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Tariq Abdelhamid- CMP831- Michigan State University 2008
Separate Strategic Planning (CPM Schedule) from Production Planning (Last Planner)

**CPM**
- CPM logic embedded in software
- High maintenance
- Managing critical path
- Focus on managing work dates
- Planning based on contracts

**Last Planner**
- Applied common sense
- Low maintenance
- Managing variability
- Focus on managing work flow
- Planning based on interdependencies
TRADITIONAL PROJECT MANAGEMENT

- LITTLE LEARNING
- MONITOR & REACT
- EXTREME FRAGMENTATION
- NO FLOW
- STRATEGIC PLANNING
- CENTRAL CONTROL
- MEETING MINUTES
- TO-DO LISTS
- MASTER SCHEDULE
- LACK OF A COMMON LANGUAGE
- LACK OF PRODUCTION KNOWLEDGE
- LACK OF TEAM COMMITMENT
- DISREGARD FOR VARIABILITY

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LEAN PRODUCTION MANAGEMENT

SHAPING WORK FLOW
IDENTIFYING & REMOVING CONSTRAINTS

DECENTRALIZED PLANNING
EXPLICIT QUALITY ASSIGNMENTS

RAPID LEARNING
MEASUREMENT

BUILDING RELIABILITY
MANAGING WORK FLOW
PRODUCTION MANAGEMENT SYSTEM
COLLABORATIVE TEAM COMMITMENT

©Lean Construction Institute, 2001
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 float 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.
- Try to make only quality assignments. Allow assignments to be rejected.
- Track PPC and act on reasons for plan failure.
Module V
Lean Construction Management

– Module V will present:

• Lean Construction Implementation
LEAN CONSTRUCTION – Where to Begin?

IMPROVE WORKFLOW RELIABILITY ON YOUR SITE!!!!!!!!!!

Waste - Muda

Variability - Mura

Overburden - Muri
Implementing Lean Construction

• The Lean way - increase workflow
  – reduce waste caused by scope changes and design errors/omissions,
    • Understand and challenge customer requirements
    • Design product and process together using cross-functional teams
    • Shift design responsibilities to suppliers
Implementing Lean Construction

• The Lean way - increase flow
  – reduce waste caused by excess inventories

• Establish strategic alliances with suppliers
  – Allows pulling inventories/material to site; concrete
  – Standardize and industrialize (prefab) wherever possible
Implementing Lean Construction

• The Lean way - increase flow
  • START USING LEAN WORK STRUCTURING
    ------WITH AS MANY STAKEHOLDERS AS POSSIBLE AND AS EARLY AS POSSIBLE
Implementing Lean Construction

• The Lean way - increase flow
  – Start by shielding production units from workflow variability by making only ‘quality’ assignments (the Last Planner System)
    – Give workers the right to say “No” to things they CAN’T do
    – Track PPC (and 5-Why the reasons for failure)

This will force the removal of variability sources but the key is to do it for overall system

Some workflow variability will remain…
Implementing Lean Construction

- Managing the remaining variability involves:

  - Location and sizing of inventory and capacity buffers. (how?)
  
  - Excess crew capacity (under loading)
  
  - Plan/Schedule buffers
  
  - Keep trying to Lower cycle times (processing + wait + inspection + handling)

  (Conventional practice overuses one of these, which one?)
Lean Production Management

• Lowering cycle times is achieved by improving Production Unit (crew) performance
  — REMOVE WASTE (NON-VALUE ADDED WORK) (Overproduction; Inventory; Material transportation; Processing; Waiting; Rework)
Value-Waste Reciprocity !!

“There is no necessary reciprocity between value and waste. Only if value is the operant variable can both waste and cost diminish.” Alan Mossman - 2006
7 Forms of Waste

Anywhere work is performed, waste is being generated and must be removed.

- **CORRECTION**: Repair or Rework
  - 5 times
- **WAITING**: Any non-work time waiting for tools, supplies, parts, etc.
- **PROCESSING**: Doing more work than is necessary
- **INVENTORY**: Maintaining excess inventory of raw materials, parts in process, or finished goods.
- **MOTION**: Any wasted motion to pick up parts or stack parts. Also wasted walking
- **OVERPRODUCTION**: Producing more than is needed before it is needed
- **CONVEYANCE**: Wasted effort to transport materials, parts, or finished goods into or out of storage, or between processes.
Another Waste Category

Koskela (2000) added “Work done in suboptimal conditions”…

- Congestion
- Rework
- Out-of-sequence work
- Multiple stops and starts
- Advanced detailed planning not possible
- Obstruction due to stocks of materials
- Work under-equipped
- Overtime
- Interruptions due to lack of materials, tools or instruction.
### Walbridge Aldinger Examples of Construction Waste

<table>
<thead>
<tr>
<th>Form of Waste</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Over-Production: Producing over the customer requirements, producing unnecessary materials/products</td>
<td>Producing more pipe spools than required</td>
</tr>
<tr>
<td>2 Inventory: Holding or purchasing unnecessary raw supplies, work-in-progress inventory, finishing goods</td>
<td>Stockpiling too much dry wall in area well before it is needed and in the way of other trades</td>
</tr>
<tr>
<td>3 Transportation: Multiple handling, delay in material handling, unnecessary handling</td>
<td>Locating materials to far from the point of installation</td>
</tr>
<tr>
<td>4 Waiting: Time delays, idle time</td>
<td>Crew B waiting for an activity to be completed as promised by Crew A</td>
</tr>
<tr>
<td>5 Motion: Actions of people or equipment that do not add value to the product</td>
<td>Double and triple handling of material when planning could have reduced it to one move</td>
</tr>
<tr>
<td>6 Over Processing: Unnecessary processing steps or work elements</td>
<td>Rubbing a concrete foundation wall to well when it will be backfilled or covered</td>
</tr>
<tr>
<td>7 Correction: Producing a part that is scrapped or requires rework /procedures</td>
<td>Punchlist items or items of work that are deficient and do not meet requirements which require rework</td>
</tr>
<tr>
<td>8 Not Utilizing Human Resources: Not following-up/implementing ideas/suggestions</td>
<td>Not considering someone’s idea to improve a process or work task particularly if that person performs that work</td>
</tr>
</tbody>
</table>
The Value Stream for the Construction Task

- Cycle Time = Processing + Handling + Inspection + Wait
- In construction:
  - Focus only on reducing *Processing (conversion)* time using technology, equipment, automation, and to some extent modularization.
  - Disregard Handling + Inspection + Wait (waste) component [part of doing the business…Easiest escape-goat is “uncertainty”]

95-99% Handling, Inspections, and Wait; Non-Essential; Waste
1-5% Processing (Conversion); Value adding
With Value Stream Mapping, you find the Construction Task

This is what you find with Work Sampling

1-5% Processing (Conversion); Value adding

95-99% Handling, Inspections, and Wait; Non-Essential; Waste
What Is Value Stream Mapping?

Planning tool to optimize results of eliminating waste

current state VSM + Lean Basics = future state VSM
An operation represents the work performed to complete the transformation of materials.

A process represents the flow of material/info in time and space as it is being transformed.

Note that construction processes do not necessarily have operations occurring in the discrete fashion shown above.
Process and Operation

• Improving an operation by reducing cycle time (processing + MUDA) will not help overall production process.

• Improving production should focus on improving all the performance of the system as a whole – the system as defined by the constituent processes.
Lean Production Management

• Lowering cycle times is achieved by improving Production Unit (crew) performance
  – REMOVE WASTE (NON-VALUE ADDED WORK)
    (Overproduction; Inventory; Material transportation; Processing; Waiting; Rework)

• Process Design (using value-stream mapping)

The next slides contain some examples of student projects. They looked at operations that were poorly designed and laden with waste.
No. of Resources
- Crew strength: 5
- Crane operator: 1
- Crane: 1
- Concrete truck operator: 1
- Concrete truck: 1

Puneet et al (2005), used with permission
Why should the truck go into the site?

Is there any value added?

Suggested Modification #1

Let the truck be parked outside, the crane can swing the bucket in the same manner from the truck to the crew pouring concrete.
What is the crane’s role? It basically is a facilitator – helps transfer concrete from truck to casting crew!

Can the truck deliver concrete directly?

Suggested Modification #2

The crane is omitted from the operation. The concrete mix truck is equipped with a chute, one that is flexible and can adjust in length and its angle. The truck can also move as per the location for casting.
Ceiling Crew in Action
Inspect Wire Hangers Before Installing

Install Wire Hangers

Inspect Metal Rails/Guides

Install Metal Rails/Guides

Layout and Measure Area

Assemble Wire Hangers

Move Hangers

Store Hangers

Delay Waiting for Next Crew Member

Install Ceiling Panels

Install "Special" Ceiling Panels

Inspect Suspended Ceiling System

Clean Up

Metal Rail/Guide Decisions

Decide wire hanger placement

Decide on "Special" Ceiling Panels

Puneet et al (2005), used with permission
Inefficiencies Observed – Ceiling Crew

- Wire hangers had to be assembled, stored, and inspected prior to installation.
- This series of tasks resulted in high percentage necessary contributory work (waste).
- The team felt that the suspended ceiling system doesn’t generate any value to the owner.
Suspended Ceiling Suggestions

• Suggestion One:
  – Utilize "Pre-assembled Wire Hangers"
    • Eliminated 4 steps in process/flow chart
  – Practicality of Suggestion:
    • Easy to implement at factory
    • Crew noted that this part usually comes assembled but did not on this particular project for unknown reasons
  – Lean Principles:
    • Shifts labor from field to factory, minimizing variability
    • Allows laborers to concentrate on value-adding, effective work instead of necessary contributory work

Puneet et al (2005), used with permission
Suspended Ceiling Suggestions, Cont.

Suggestion Two:

– **Eliminate** ceiling system all together
– *Spray Paint* exposed mechanical components
– Practicality of Suggestion:
  • Easy to implement
  • Improves cost and reduces time on schedule
– Lean Principles:
  • Team felt the suspended ceiling system added minimal, if any, value to the owner
  • Painted system allows easier access to mechanicals from a facilities management (owner’s) perspective
Rebar for the slabs of this parking ramp was handled multiple times before it arrived to its final location. See process map on the next slide.
REBAR FOR SLAB

Flow diagram

- rebar from the truck
- transported by crane to the site near the actual place of work
- accumulate on the site
- carried by labor to the deck
- accumulate on the deck
- carried by rodman to the work point
  - place rebar
  - inspect and corrections
  - tie rebar

Currently practised method of construction

Barshan al (2002), used with permission
Using the crane to directly place the rebar on the deck, using only one labor

Flow diagram
- rebar from truck
- transported by crane to the site on the deck forms
- accumulated at the point of work
- place rebar & inspect
- tie rebar

Barshan al (2002), used with permission
PROPOSAL 2

Using Prefabricated panels, transported by crane into place

Flow diagram

- Pre fabricated panels arrive on site
- inspect
- Transported into place by crane
- put in place by laborer
- fasten to the deck
Lean Production Management

• Improving Production Unit (crew) performance
  – REMOVE WASTE (NON-VALUE ADDED WORK)
    • Process Design
    • Off-site fabrication and JIT
      – Establish strategic alliances with suppliers

The next slides show examples of off-site fabricated items that are delivered to the site when required and convert the construction site to an assembly location.
Cellcast™
Floor System

Concrete frame construction

Note: Sprayed-on fireproofing is required under all deck units to achieve a 1,2, or 3 hr fire rating. Refer to UL Designs D 871 or D 739 for required thicknesses. Fireproofing not by HHRFS.
Lean Production Management

• Improving Production Unit (crew) performance
  – REMOVE WASTE (NON-VALUE ADDED WORK)
    • Process Design
    • Off-site fabrication and JIT
      – Establish strategic alliances with suppliers
    • Visual Site
Lean Production Management

- Improving Production Unit (crew) performance
  - REMOVE WASTE (NON-VALUE ADDED WORK)
    - Process Design
    - Off-site fabrication and JIT
    - Visual Site
    - 5S Everything in its place and a place for everything
6S [Workplace Organization]

- **Sort**: Clearly Distinguish Needed Items from Unneeded
  - Keep needed items in the correct place to allow for easy and immediate retrieval.

- **Sustain**: Make a habit of maintaining established procedures.
  - Keep the workshop swept and clean.

- **Safety**: Identify danger and hazard.
  - The safe way is the best way.

- **Standardize**: Consistently applying 6S methods in a uniform and disciplined manner.

- **Shine**: Keep the workshop swept and clean.
  - Consistently apply 6S methods.

- **Straighten**: Keep needed items in the correct place to allow for easy and immediate retrieval.

- **Salvage**: Not do not touch.
  - Salvage not do not touch.

Tariq Abdelhamid- CMP831- Michigan State University 2008
Lean Production Management

• Improving Production Unit (crew) performance
  – REMOVE WASTE (NON-VALUE ADDED WORK)
    • Process Design
    • Off-site fabrication and JIT
    • Visual Site
    • 5S Everything in its place and a place for everything
    • Built-in Quality (in-line quality)
    • Daily Crew Huddles (where are you going to be by noon, is there a better way to do this work, is it safe?)
Quality leads to Safety

Deming’s Quality chain reaction

Improve quality

- Costs decrease — less rework, fewer accidents, mistakes, delays, snags; better use of equipment and materials

Productivity improves

- Capture the market with better quality and lower price

Stay in business

- Provide jobs and more jobs

Module VI
Lean Construction Management

– Module VI will present:

• Summary
# LC Levels of implementation

<table>
<thead>
<tr>
<th>Level</th>
<th>Features</th>
<th>Tools</th>
<th>Involved/ Benefiting Party</th>
</tr>
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<tbody>
<tr>
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<td>Improved Work Coordination</td>
<td>LPDS: LPS®</td>
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LEAN CONSTRUCTION – Where to Begin?

Level 1

IMPROVE WORKFLOW RELIABILITY ON YOUR SITE!!!!!!!!!!!!!!!!!!!!

- Waste - Muda
- Variability - Mura
- Overburden - Muri
- Proactive Safety
- VSM, 5S, visual site
- Last Planner System®
# LC Levels of implementation

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Implementing Lean Construction

Level 2

• The Lean way – Production System Design to Increase Workflow Reliability
  – Lean work structuring will reduce waste caused by scope changes and design errors/omissions,
    • Understand and challenge customer requirements (BIM)
    • Shift design responsibilities to suppliers (BIM, SCM)
Implementing Lean Construction

Level 2

• The Lean way – Production System Design to Increase Workflow Reliability

  – Lean work structuring will reduce waste caused by scope changes and design errors/omissions,

  • Design product and process together using cross-functional teams
    – Simulation
    – First-run studies

©Lean Construction Institute, 2001
Adapted by T. Abdelhamid
Implementing Lean Construction

Level 2

• The Lean way – Production System Design to Increase Workflow Reliability
  – Lean work structuring will reduce waste caused by excess inventories
  • Establish strategic alliances with suppliers
    – Allows pulling inventories/material to site; concrete
    – Standardize and industrialize (prefab) wherever possible
## LC Levels of implementation

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Implementing Lean Construction

Level 3

- The Lean Way - Integrated Project Delivery Or Relational Contracting to Increase Workflow Reliability
  - This will allow the Architect and CM/GC and Subs to impact the programming (Project Definition) phase.
Results

• Pacific Contracting increased their annual turnover by 20% in 18 months with same staff
• Neenan Company reduced project times and cost by up to 30%
• “If we can get the construction community to embrace these methodologies, it will make every person perform their jobs better. And I think that’s exciting. It will make us better, more efficient, and probably more profitable” Dan Wojtkowski, network director for design and construction – SSM Healthcare
• "Lean lowers the 'hair-on-fire' index on our jobs." - Linbeck Construction
• "First, Lean is simply systematically applied common sense. Second, it is counterintuitive. Unlike anything I've seen before, it causes us to rethink how we manage work. And, finally we saw it as an opportunity to deliver high value facilities to the marketplace in shorter time." Paul Reiser, Boldt's vice president for production process innovation,
Lean project delivery was highlighted in:

- ENR’s cover story of the lean initiative at Sutter Health (Nov. 26, 2007)
- CURT’s national conference: “LEAN Projects from an Owner Perspective” and “Integrated Form of Agreement: A Relational Contracting Style That Works,” in Naples, FL (Nov. 7, 2007)
- The launch of ConsensusDOCS, featuring the LCI version of the Integrated Form of Agreement (Sept. 28, 2007)
- CII’s annual conference, featuring the research report, “Roadmap for Lean Implementation at the Project Level,” in Orlando, FL (Aug. 1, 2007)

- The cover story of The VOICE magazine for CURT members (Summer 2007)
- The 15th Annual Conference of the International Group for Lean Construction in East Lansing, MI (July 18-20, 2007)
- CURT’s member workshop, “This Changes Everything,” with presentations by LCI members, in Phoenix, AZ (Apr. 11, 2007)
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<td>Focus is on the production system</td>
<td>Focus is on transactions and contracts</td>
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<tr>
<td>Task, Flow &amp; Value</td>
<td>Task Goal</td>
</tr>
<tr>
<td>Downstream players are involved in upstream decisions.</td>
<td>Decisions are made sequentially by specialists and ‘thrown over the wall’</td>
</tr>
<tr>
<td>Product and process are designed together</td>
<td>Product design is completed, then process design begins</td>
</tr>
<tr>
<td>All product life cycle stages are considered in design</td>
<td>Not all product life cycle stages are considered in design</td>
</tr>
<tr>
<td>Activities are performed at the last responsible moment</td>
<td>Activities are performed as soon as possible</td>
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<td>Systematic efforts are made to reduce supply chain lead times</td>
<td>Separate organizations link together through the market, and take what the market offers</td>
</tr>
<tr>
<td>Learning is incorporated into project, firm, and supply chain management</td>
<td>Learning occurs sporadically</td>
</tr>
<tr>
<td>Stakeholder interests are aligned</td>
<td>Stakeholder interests are not aligned</td>
</tr>
<tr>
<td>Buffers are sized and located to perform their function of absorbing system variability</td>
<td>Participants build up large inventories to protect their own interests</td>
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© Lean Construction Institute 2003, used with permission.
What is “LEAN” Construction?

“A way to design production systems to minimize waste of materials, time, and effort in order to generate the maximum possible amount of value."

Lean Construction

• "A coherent production management philosophy and set of practice designed to maximize value in the delivery of projects to owner/client by improving site-level production planning, execution, coordination, and control through a systematic elimination of inefficiencies in the design process, the supply chain structure, and the construction operations that impede the continuous flow of material and information on a construction project."
What is “LEAN” Construction?

The pursuit of concurrent and continuous improvements in the entire supply chain (design, procurement, construction, operations, and maintenance) to deliver value per agreement with the owner.
• The following are definitions of Lean Construction from the point of view of others
What is “LEAN” Construction?

• Lean Construction is a “way to design production systems to minimize waste of materials, time, and effort in order to generate the maximum possible amount of value”.

• “Lean construction is not just another specific approach to construction, but rather a challenger of the conventional understanding and practice of construction.”

What is “LEAN” Construction?

• **What is Lean Construction?**
• **Lean Construction** is a production management-based approach to project delivery -- a new way to design and build capital facilities. **Lean production management** has caused a revolution in manufacturing design, supply and assembly.

• Applied to construction, Lean changes the way work is done throughout the delivery process. Lean Construction extends from the objectives of a lean production system - maximize value and minimize waste - to specific techniques and applies them in a new project delivery process. As a result:

  – The facility and its delivery process are designed together to better reveal and support customer purposes. Positive iteration within the process is supported and negative iteration reduced.
  – Work is structured throughout the process to maximize value and to reduce waste at the project delivery level.
  – Efforts to manage and improve performance are aimed at improving total project performance because it is more important than reducing the cost or increasing the speed of any activity.
  – "Control" is redefined from "monitoring results" to "making things happen." The performance of the planning and control systems are measured and improved.

The reliable release of work between specialists in design, supply and assembly assures value is delivered to the customer and waste is reduced. Lean Construction is particularly useful on complex, uncertain and quick projects. It challenges the belief that there must always be a trade between time, cost, and quality

[www.leanconstruction.org](http://www.leanconstruction.org)
What is “LEAN” Construction?

- Wlabridge Aldinger defines LC through its features and requirements... LC is a process that:
  - Reduces Waste
  - Saves Money and Reduces Cost
  - Creates Higher Quality
  - Creates Flexible Delivery Systems to Match Owner Requirements
  - Creates Stable Schedules
  - Reliable Material Deliveries and Reliable Workforce
  - Promotes Employee Participation, Which Leads to Satisfaction
  - Improves Customer Satisfaction
  - Requires a Cultural Change.

(http://www.walbridge.com/lean/index.htm)
What is “LEAN” Construction?

“The right people talking about the right things at the right time at the right level of details”

Greg Howell – LCI
What is “LEAN” Construction?

Come together to:

- Have work flow in a coordinated manner
- Design a production system
- Align interests, share wealth, and define value

- Greg Howell (2008)
• Who is doing it?

Owners: Sutter Health, Intel, Ford, Solutia, Rice University, BAA

Designers: IDC, Neenan, Burt Hill, Kosar Rittelmann, NIRAS, Albert Kahn, Ghafari


• Lean Construction Institute

visit http://www.leanconstruction.org
- Holds an annual Lean Construction Congress
- Conducts seminars and workshops on LC
- Contributing corporate members fund the institute to conduct research projects
- Individual membership is available
LC Teaching and Research

- The International Group for Lean Construction (IGLC) holds an annual conference
- US and International universities teaching and performing research in Lean Construction:

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These materials were developed as part of MSU’s CMP831 course on "Lean Construction". Most of the materials are developed, modified, and/or adapted by the instructor, Tariq Abdelhamid. In some cases, materials were developed by student teams. There are materials that also belong to other authors (as referenced and cited). The materials in this presentation is to be used strictly for non-revenue producing educational purposes. Any other use must be approved by Tariq Abdelhamid (tariq@msu.edu). Use of copyrighted material that is not the property of this author must first obtain the permission of the listed author(s).