BIM, LEAN AND ADVANCED WORK PACKAGING
HOW DO THEY FIT TOGETHER?

ZUHAIR HADDAD
CIO – CCC/ CCT
http://www.cctintl.com/
THE INNOVATIVE PLATFORM FOR EFFICIENT, LEAN AND TRANSPARENT CONSTRUCTION PROCESS MANAGEMENT

ENABLING DIGITAL TRANSFORMATION OF CONSTRUCTION
Critical path method (CPM) schedules (primavera P6, Microsoft project and similar) follow a top down approach to construction project execution not focusing on the process and mostly neglecting the inter-relations of multiple crews working in same construction zones.

The result is typically obstruction of crews rushing their way to individual completion of tasks planned in the schedule.
There is a high customer need in the market for online collaboration and disruptive planning tools - LCM Digital® is the only answer in the market.

Digital changes are massively pushing the market.

What we do better...

- **Lean approaches** are needed in the construction industry – we use our chance.
- **Digital integrated construction processes** help us overcome current problems on site.
- **We are using the data**: more data collection, data analytics, benchmarks and machine learning.
- **Business Intelligence**: the availability of qualified real-time data offers a high quality basis for scheduling, design, integration, logistics and supply chain.
- **Integrated digital workflows**: digital connection of information leads to a very efficient and productive communication and work results.
- **BIM is standard**: offering data to bridge the gap between the process and material availability as well as online and onsite navigation.
- **We make mobile working happen**, collaboration and communication is redefining the way we work together.
Plan your Strategy:
Segmentation of typical work and takt areas to define process flow, team performance and duration

Plan your construction flow:
Use the typical takt areas to define your construction flow (takt trains) by replication for a continuous flow and optimal resource usage. Update your plan based on Live Data from site and supply chain data

Production management on site:
Set your plan into action with a production management system on site using Kanban boards and the LCM Digital App for Live Updates.
STABILITY CRITERIA/ FRONT END LOADING

Standard Processes

BIM

Design / Engineering

Supply Chain

AI

LCM

LEAD CONSTRUCTION MANAGEMENT
CHANGING THE WAY OF CONSTRUCTION MANAGEMENT

Consistent process from strategy to site

Standard processes

Takt planning

Easy to use

Cloud based collaboration platform

Build on the knowledge of your team

Increase the takt rate of your construction project

BIM connected

Getting everybody on board to get the job done

Easy to use on site, everyday

Knowing what is going on for a better management

Combining all digital information for better projects
LCM® takt planning has been proven in over 450 projects over the past 12 years, improving project performance with every project

There is no other cloud-based product as comprehensiveness and with full service as LCM®

LCM digital® runs on different platforms and browsers for PC, Mac, iPad, etc.

We have a strong vision - the next steps implementing AI and supply chain management are already on the way
BENEFITS FROM DIFFERENT PERSPECTIVES

LCM DIGITAL® WORKS FOR DIFFERENT CUSTOMER GROUPS

Owners
Project management and site management

Project involved construction companies
OUR ANALOG ROOTS - MAKING PROBLEMS VISIBLE AND ELIMINATING THEM
Our Lean Philosophy

Many resources are used to cover problems. Problems are covered!

Create transparency, reduce water. Problems become visible!

Problems have been reduced or eliminated. Causes are permanently eliminated!

Problems are often covered by an heightened use of resources – Lean Process Management helps to identify and eliminate the causes behind this CIP.

CIP = continuous improvement process

Traditional approach

Lean approach
THE CONTENT & AREA DEFINITION

Define Zone Types
Areas with same work sequence
(Class of Rooms)

Overall Process Analysis
Fragnet Concept

Define Takt Types
Area type that can be combined in a takt train
(Subclass of Rooms by Size or minor work difference)

Takt Analysis

Define Takt Zones
Areas on site that are combined in a takt train sequence
(Instances per subclass)

Takt Planning

Process Mapping and Sequencing

Process Planning (Overall takted production schedule)

- Construction Flow Sequence,
- Leveling
- Resource Optimization

- Scheduling
- Management & Optimization
- Controlling & Report

Daily Kanban Board

Daily update 3-4 weeks production schedule

QR Code & APP

Daily update 3-4 weeks production schedule
ZONE TYPES DEFINITION – CLASS OF ROOMS

Define Zone Types
Areas with same work sequence

(Class of Rooms)
Define Takt Types
Area type that can be combined in a takt train
(Subclass of Rooms by Size or minor work difference)
TAKT ZONES DEFINITION – ACTUAL Instances of SUBCLASS

Define Takt Zones

Areas on site that are combined in a takt train sequence

(Instances per subclass)
Aim
To provide transparency, create a common understanding of process steps and early identification of problems and bottlenecks.

Description
The process of creating the optimal process sequence for each zone type (working area)
TAKT ANALYSIS – FRAGNET DURATIONS

Aim
To prepare the overall process analysis to transform into an optimal process plan populated with all the relevant parameters.

Description
The process of adding 3 dimensions namely duration, material and manpower to the overall process analysis.
DEFINE TAKT ZONES – NAMING CONVENTION

Define Takt Zones
Areas on site that are combined in a takt train sequence
(Instances per subclass)

For All Selected Takt Types:
N=1;
For Takt Type:

Create Takt Zone = Area+SubArea+TaktType+N;
N= N+1;

Generate Takt Zones

SELECT TAKT TYPE:
- Bathroom
- Kitchen
- Master Bedroom

SELECT AREA:
- Building1-F1to10

DEFAULT COUNT:
1

AREA - SUB AREA
BATHROOM  KITCHEN  MASTER BED...

Building1-F1to10 - B1-F1
3  1  2

Building1-F1to10 - B1-F2
3  1  2

Generate Takt Zones
<table>
<thead>
<tr>
<th>Name</th>
<th>Image</th>
<th>Zone Type</th>
<th>TakT Type</th>
<th>Area</th>
<th>Subarea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building 1-F1019 - B1-F1 - Bathroom - 1</td>
<td></td>
<td>Bathroom</td>
<td>Building1-F1019</td>
<td>B1-F1</td>
<td></td>
</tr>
<tr>
<td>Building 1-F1019 - B1-F1 - Bathroom - 2</td>
<td></td>
<td>Bathroom</td>
<td>Building1-F1019</td>
<td>B1-F1</td>
<td></td>
</tr>
<tr>
<td>Building 1-F1019 - B1-F1 - Bathroom - 3</td>
<td></td>
<td>Bathroom</td>
<td>Building1-F1019</td>
<td>B1-F1</td>
<td></td>
</tr>
<tr>
<td>Building 1-F1019 - B1-F1 - Bathroom - 4</td>
<td></td>
<td>Bathroom</td>
<td>Building1-F1019</td>
<td>B1-F1</td>
<td></td>
</tr>
<tr>
<td>Building 1-F1019 - B1-F1 - Bathroom - 5</td>
<td></td>
<td>Bathroom</td>
<td>Building1-F1019</td>
<td>B1-F1</td>
<td></td>
</tr>
<tr>
<td>Building 1-F1019 - B1-F1 - Master Bedroom - 1</td>
<td></td>
<td>Master Bedroom</td>
<td>Building1-F1019</td>
<td>B1-F1</td>
<td></td>
</tr>
<tr>
<td>Building 1-F1019 - B1-F1 - Master Bedroom - 2</td>
<td></td>
<td>Master Bedroom</td>
<td>Building1-F1019</td>
<td>B1-F1</td>
<td></td>
</tr>
<tr>
<td>Building 1-F1019 - B1-F1 - Regular Bedroom - 1</td>
<td></td>
<td>Regular Bedroom</td>
<td>Building1-F1019</td>
<td>B1-F1</td>
<td></td>
</tr>
<tr>
<td>Building 1-F1019 - B1-F1 - Regular Bedroom - 2</td>
<td></td>
<td>Regular Bedroom</td>
<td>Building1-F1019</td>
<td>B1-F1</td>
<td></td>
</tr>
</tbody>
</table>
TAKT PLANNING

Aim
To allow for an iterative process to find the most efficient process plan in terms of manhours and quantities.

Description
The process of sequencing takt zones using takt trains, dependencies and time intervals.
PROCESS PLANNING

Overall Process Analysis → Takt Analysis → Takt Planning

**Description**

The process of fine tuning the takt analysis and takt planning applied to all the takt zones and assigning the work of the next n weeks to specific teams.

**Aim**

Have an overview/detailed view of the schedule, front-end loading and proactively managing stability criteria.
TO TAKT OR NOT TO TAKT? THAT IS THE QUESTION...

- Takt planning is the process of trying to harmonize the durations for every wagon in the train so as to keep the train moving together.
  - If the blue wagon takes 2 times the duration of the other wagons, the tail end of the train will fall behind every week.

- We need a disruptive process to find an optimum solution.
CIFE Research in Collaboration with CCC

A Method to Quickly Generate Close-to-optimum Look-Ahead Schedule (LAS) for the Finishing Phase

Ning (Tony) Dong

PhD Committee:
Principle Advisor – Prof. Martin Fischer
Industrial Advisor – Mr. Zuhair Haddad
Prof. Raymond Levitt
Assist. Prof. Dongdong Ge
Why do we need a good LAS?

- A guidance to provide correct work sequence
- A shared means to prevent work conflict
- A whiteboard to provide improved awareness of resource utilization

Ultimately, a good LAS should be a way of presentation after pulling all different data sources together to (1) facilitate coordination among various project participants; (2) be actually used by the people from job site to guide field work and (3) become a means of project monitor and control (i.e., progress monitoring, crew/material forecasting, material reporting, etc.)
Why a good LAS is so important in the finishing phase? – complex network

Activity network/fragnet for the finishing of one faculty room at CMU Qatar
Why a good LAS is so important in the finishing phase?

GC needs to manage in the actual project:

- More than 200 rooms;
- More than 20 types of self-performed operations on average per room;
- More than 16 types of rooms (work sequence);
- More than 20 types of subs’ operations;
- More than 80 types of materials;
- More than 10 types of skilled workers/crews
Why a good LAS is so important in the finishing phase? - constraints

Corridor Access Constraint

Zone Constraint

Spatial Constraint
Why a good LAS looks like in the finishing phase?

Room ID

Room-centered View of LAS

Work Days

Who

What

When

Where
What a good LAS looks like in the finishing phase?

Room-centered View of LAS

Install Conduit & Box → Plastering → Screed → Painting
What a good LAS looks like in the finishing phase?

Crew-centered View of LAS

- Crew ID
- When
- What
- Who
- Where
Simulation Overall Description

User Input:
- Number of different types of crews
- Starting/available date of each room
- Duration of an operation when it is hard to calculate its actual length
- Corridor constraint, zone constraint, cost related inputs, etc.

Site Input:
- Composition and productivity of crews
- Fragnet (work sequence in a workspace/room)
- Quantities

System Output:
- Look-ahead schedule; crew daily work plan
- Project duration, cost, crew idle ratio, room idle ratio and other parameters.
Inputs:

- 6-room case
- Crew availability = 1-1-1-1-1-1-1
- All six rooms have the same priority and the same starting date
- One corridor constraint
- One zone constraint
- Run simulation 10,000 times
Demo1 - Schedule Random Generation

Six-room activity network
Demo1- Schedule Random Generation

Users can choose to change the crew inputs according to the availability on site.
Random Simulation Schedule Generation Process

- Find available rooms
- Allocate crew to room
- Update one day’s work & release resources

Next ROOM

Next DAY

Zuhair Haddad’s Schedule Generation Schema
Project duration ranges from 74 to 99 days.

Time spent on this simulation: 8.7 minutes.
The project cost ranges from $22,900 to $28,800.

The minimum project cost found is $22,900. The corresponding project duration is 77 days.

The shortest project duration does not necessarily entail minimum project cost.

Relation between project duration and cost
Sample look-ahead schedule generated:

Zone 1: The HVAC related operation must be done simultaneously in these three rooms.

The gray cells represent the days a room is idle for the lack of crew or the restriction of certain constraints.

Corridor access constraint: when the suspended ceiling operation is on in the corridor, no access to the adjacent rooms because of scaffolding.

Resource-cost analysis:

When we keep the crews as busy as possible, we do not necessarily get the shortest schedule.

When we keep the crews as busy as possible, we could get the schedule with minimum cost.
Using GA to find optimized schedule

- Initiation
- Population
- Reproduction
- New generation
- Mutation
- Selection
- Parents

Diagram:
- Population
- Reproduction
- New generation
- Mutation
- Selection
- Initiation
Demo2 – GA1 Fixed Crew Availability

GA Inputs:

- crew availability = 1-1-1-1-1-1-1-1;
- crossover rate = 0.4;
- mutation rate = 0.4;
- population size = 200;
- generation = 40;
Demo2 – GA1

GA Inputs:

- time spent on this simulation: 3.5 minutes
- the minimum project cost found is $22,580, the corresponding duration is 75 days.
GA1 vs. Random – 20-room example

- Population Size - 360;
- Number of Generation – 360;
- Crossover rate = 0.6, mutation rate = 0.2;

<table>
<thead>
<tr>
<th>Crew Avai.</th>
<th>GA</th>
<th>Random (10,000 runs)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CPU Time Spent (hr.)</td>
<td>Min Cost (USD)</td>
</tr>
<tr>
<td>2-2-2-2-2-2-2-2</td>
<td>5.53</td>
<td><strong>53,360</strong></td>
</tr>
<tr>
<td>3-3-3-3-3-3-3-3</td>
<td>4.82</td>
<td><strong>48,540</strong></td>
</tr>
<tr>
<td>4-4-4-4-4-4-4-4</td>
<td>2.70</td>
<td><strong>46,520</strong></td>
</tr>
<tr>
<td>5-5-5-5-5-5-5-5</td>
<td>2.15</td>
<td><strong>47,680</strong></td>
</tr>
</tbody>
</table>
Add Crew selector

- Add a new paradigm to find the optimum crew configuration (number for each type of crew)
- Initial run assumes unlimited crews
- Result is maximum number of crews that can be utilized
- For every subsequent run of the simulator, the decider uses the random number generator to decide number of each type of crew available
Demo3 – GA2, unknown crew availability

GA Inputs:

- Six-room case
- crossover rate = 0.2;
- mutation rate = 0.6;
- population size = 200;
- generation = 40;
Demo3 – GA2, unknown crew availability

- In around 7 minutes, GA2 found a schedule with the minimum project cost of $22,200, the corresponding project duration is 68 days.
- Crew configuration found is: 1-2-2-1-1-1-1
- Note in Demo2, when the fixed crew availability is 1-1-1-1-1-1-1, the minimum project cost found by GA1 is $22,580, the corresponding project duration is 75 days.
- In Demo1, when the fixed crew availability is 1-1-1-1-1-1-1, the minimum project cost found by Random is $22,900, the corresponding project duration is 77 days.
- So GA2 actually can help us more to find the best crew configuration to reduce both time and cost.
WORKFACE PLANNING

- 3D Model
- Visual Reporting
- Lean Construction
- Advanced Work packaging
- Engineering Data
- BIM Controls
- Planning
IWP – TAKT ZONE

- Foundation IWP
- Steel Structure IWP
- Piping IWP
- Electrical IWP
OPTIMIZING IWPs

- Each IWP is a takt zone.
- Each IWP has a fragnet.
- A train will pass through all homogenous IWPs (underground for all pipe racks, etc.)
- With the lean-board/ simulator, we can optimize execution of workface planning.
FRAGNET FOR UNDER-GROUND IWP/ TAKT ZONE

- Fragnet for Under-ground IWP
  - Excavate to -2
  - Foundations
    - Rebar
    - Concrete
    - Formwork
- Under-ground piping
  - Pipes
  - Manholes
  - Backfill to -1
  - Foundations
  - Etc.
C3D LEANBOARD

Models and MTO
- Import 3D BIM Models (.IFC)
- Import Material Take - Off
- Import BOQ Cost Rates

WBS Setup
- Import Process Plan
- Linking Process Plan to 3D Model
- Linking Construction Steps to 3D Model

OBS
- Defining Subcontractors and Crews in C3D
C3D LEANBOARD

**BOQs to Operation Assignments**

| Operation | Description | Material Code | Unit | Material Description | | Controlling BOQ |
|-----------|-------------|---------------|------|----------------------|-------|
| Funda1    | Attention   | 0-5-02        | m²   | Fundament_Attention  | False |
| Funda2    | Attention   | 0-5-03        | m²   | Fundament_Attention  | False |
| ...       | ...         | ...           | ...  | ...                  | ...   |

**Operation Quantities Calculations**

**Project division into parts of Construction**

B
C3D LEANBOARD

Planning using Leanboard

Methods
- Crunch
- Simulator

Lean Cards

Barcode Scanning

Progress Entered in C3D

Planned Quantities and Cost Reports

Quantity Reports Per Activity

Progress Reports:
- 4D Animations
- 3D Colorizations based on Progress
- PDF/Excel Reports
C3D’s LEAN BOARD CURRENT IMPLEMENTATION

- Suurstoffi – Switzerland (CIVIL)
- ZIRCU – ABU DHABI ZIRCU ISLAND (OIL&GAS)
- GHAZEER GAZP – OMAN (KHAZZAN BLOCK 61) (OIL&GAS)
- FGP – KAZAKHSTAN (TENGIZ)(OIL&GAS) (PENDING)
THANK YOU

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