Virtual Design and Construction in Support of Construction Engineering

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Design and construction planning methods have changed significantly in the last 40 years.

Picture courtesy Fluor

Picture courtesy DPR
As have constructibility review and construction communication methods

Picture courtesy Fluor

Picture courtesy Accu-Crete
Virtual Design and Construction (VDC) combines:

Client/Business Objectives

Project Objectives

BIM+

ICE

Process

NOTE: Drawings are batched into sections—then subdivided into building components. Each component is an assembly package, e.g. rail box floor, wall, etc. The number of drawing sheets per building component vary depending on the work. On ART for example, each component may consist of 8-15 GA drawings and 8-15 RC detail drawings.

NOTE: Design changes during detailing (from: architecture, baggage, systems, etc.) are upsetting RC drawing development.

Most of the checking process is done concurrently with RC detail development.

BAA building control accepts the opinion of the independent design check — and does not perform a check of its own.
• If you cannot build it virtually you won’t be able to build it in reality.
• An engineer can model faster and more cheaply than a crew can install the same components.
• What you see is what you get.
• Visualizations enable creativity.
• Sooner or later you pay for integration.

• Why do we let latency govern project duration?
• Why do 6 of 10 design engineers spend all their time managing information?

• What you (performance) model is what you get.
If it doesn’t fit in the 3D model it won’t miraculously fit in the field

Picture Courtesy DPR
Are the budget, work methods, and schedule aligned?

- 2D data and schedule with 200+ activities for a 1,000,000+ sf office complex
- 252 hours of 3D modeling, 200 hours of 4D modeling
- Used extensively for pre-bid constructibility reviews
- Discovered $3 million in savings for unexcavated courtyards and parking structure redesign
- Discovered opportunities to save $5 million in overall
Is the secant pile wall really constructible on the South side?

- Allows start of EXC. early.
- Do we still need a wall on South if one is on North?
- Removes the constraint of WATER Proofing here.
Video clips shown

• Installing a column rebar cage by SPS (see http://www.vimeo.com/15465074)
• Detailed construction engineering of rebar for a pile extension (http://www.vimeo.com/15467505)
• 90-day look-ahead schedule for the Walt Disney Concert Hall by Mortenson (see http://www.vimeo.com/7478800)
Identify critical interactions between design and construction sequence

Architectural concrete and curtain wall work cannot take place in parallel

Pictures Courtesy Mortenson
Streamline Materials

- Visualize Materials On Site
- Track Purchase Orders / ETAs
- Drive Trial Allocation Priorities
- Bag-and-Tag By Work Pack
Virtual Work Packs – 4 Views
ConstructSim – Status Visualization
## C3D Based Project Visual Planning & Controls in Saudi Embassy Project (SEP), Cairo

### Plan Name: ES Plan
### Starting Period: 100

#### Floor Level: 10

<table>
<thead>
<tr>
<th>Building</th>
<th>Floor</th>
<th>Activity</th>
<th>Activity Description</th>
<th>Last Week Actual</th>
<th>Last Week Target</th>
<th>This Week Actual</th>
<th>This Week Target</th>
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<th>Week 1 Target</th>
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<th>Week 2 Target</th>
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Clearly communicate assembly instructions to the field crews.
Effective Planning through Virtual Mockups

“Assembly Drawings” for construction!

Exempla Lutheran Medical Center – Wheatridge, CO – CM/GC

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Supporting the human and machine workflow with a 3D information model

- SPS and project partners:
  - Cycle time of design review reduced from 5-6 weeks to 2-3 weeks
  - Lead-time on rebar reduced from 10 days to 3 days
  - Onsite RFI's were reduced by 80%
  - If necessary, detailing-fabrication-delivery of rebar within 5 days
Rebar Production Process

Engineering

Fabrication & Assembly

Installation

3 Days

2 Days

2 Days
Visual and data models support …

- allocation of materials
- deployment of construction-applied resources
- understanding of field construction knowledge
to
- test constructibility of design and construction methods
- communicate design and construction information
- create a better and sharable information basis for the current project and future projects
- rapidly close the loop between planned and actual performance

for
- improved safety, productivity, and environmental performance

10 steps are from Bob Bittner’s presentation at the conference.
First 3 bullets on the left are from Bob Tatum’s categories of construction engineering knowledge presented at this conference.
LEVEL 4: SIMULATE FOR OPTIMAL SOLUTION

Formwork modeling on the UC Santa Cruz project helped determine the appropriate reuse of formwork.
Prefabricated drywall panels based on a coordinated BIM on a large healthcare project
Materials and assemblies can be fabricated with increasingly high accuracy.

Max Boegl produces slab tracks for high-speed rail projects with 0.1 mm tolerance.

Model utterstock Measurement etSocketAddress Fabrication/Production

Pictures from http://www.max-boegl.de
Stageworks: Real-time schedule control

Data obtained over 30 possessions indicated 69% productive use of available worksite time.
Automatically Generating Look-Ahead Schedules for the Finishing Phase
N. Dong, M. Fischer, R. Levitt, D. Ge, Zuhair Haddad, CCC

Existing methods and tools did not support the quick assignment of 50 crews to 100s of activities in 200 rooms every day.

- Automated Schedule Generation
- Resource Constrained Scheduling
- Artificial Intelligence

Three constraints that trouble the engineers most when scheduling for the finishing phase (picture source: CCC)

Various room finishing types of CMU university project at Qatar (source: CCC) – rooms are color coded by type

Activity on node network of the finishing of one faculty office, activities are color coded by discipline (source: CCC)

Project Databases
- Scattered Data
- Integrated Data

Information Model
- LAS Gen. Schema
- Initial Schedules

Genetic Algorithm
- Optimal Schedule(s)

www.stanford.edu/~ningdong/LASproject/
The results of automated progress detection

Residence Hall Construction Project photolog (160 image)

Slide courtesy Mani Golparvar-Fard
Practical Significance

- **Safety Management**
  - Remote safety analysis
  - Potential automation of identification of unsafe locations/components

- **Visualization of Sustainable Construction (LEED2009 points)**
  - Sustainable Sites
  - Materials and Resources
    - Recycled Content
    - Regional Materials

Slide courtesy Mani Golparvar-Fard
Comparing construction methods

Work with Rogier Jongeling, Lulea Univ. Tech., Sweden