Building Information Modeling Support for Production Control On Site

Assoc. Professor Rafael Sacks

Virtual Construction Lab
Civil and Environmental Engineering
Technion - Israel Institute of Technology
SECOVI
Advanced BIM Seminar
São Paulo, 26th July 2011

BIM - Modelo de Informação da Construção
Suporte para controle de produção insitu

Assoc. Professor Rafael Sacks

Virtual Construction Lab
Civil and Environmental Engineering
Technion - Israel Institute of Technology

© Copyright 2011 Rafael Sacks
Contents

- The Problems
- Lean Developments
- BIM Developments
- Lean and BIM Synergies
- KanBIM
- Research Agenda
Contents

• Os desafios
• Tendências de desenvolvimentos enxuto
• Tendências de desenvolvimentos BIM
• Sinergia entre desenvolvimento enxuto e BIM
• KanBIM
• Cronograma de pesquisas
Empire State Building
Construction speed for the world's 100 tallest building built between 1929 and 2007

Empire State Building

**Completed in 410 days – with no critical path!**

---

The Problems

Lean Developments

BIM Developments

Lean and BIM Synergies

KanBIM

Research Agenda

Possible explanations

• Economic environment of the Great Depression.....
  – but in 1929 the Bank of Manhattan, a 77-story building, was completed in less than one year.

• Variation and complexity of the building form.....
Possible explanations

• Increased **product** complexity – more and more complex building systems....
  – but adding the basic durations for these does not explain the change.
One Island East, Hong Kong
Possible explanations

- Increased **product** complexity – more and more complex building systems....
  - but adding the basic durations for these does not explain the change.
- Increased **process** complexity
- Increased **organization** complexity
The Problems

Increased **Process** Complexity

- Design changes during construction
- Re-entrant work
  - Crews return to the same place multiple times
- Reciprocal interdependence
  - Crews are required to work together
Project Organization Complexity

The Problems

Lean
Developments

BIM
Developments

Lean and BIM
Synergies

KanBIM

Research
Agenda

Finance

Community

Government

Designers
Managers

Builders

Operators
Owners
Users

Subcontractors
Ropemaker Office Building, London

The Problems

Lean Developments

BIM Developments

Lean and BIM Synergies

KanBIM

Research Agenda

CLIENT (British Land)

Construction Manager (MACE)

Engineering Designers (ARUP)

TRADE CONTRACT

Manage

Verify and Check

Foundation Package

Structural Concrete Package

Structural Steel Package

Mechanical Package

Electrical Package

Curtain Wall Package

Masonry Walls Package

Drywall Package

Sub #1

Sub #2

Sub #3

Sub #4

Sub #5

Sub #6

Sub #7

Sub #8

Sub #9

Sub #10

Sub #11

Sub #12

Sub #13

Sub #14

Sub #15

Sub #16

Sub #17

Sub #18

Sub #19

Sub #20

Civil and Environmental Engineering
Technion - Israel Institute of Technology

© Copyright 2011 Rafael Sacks
Complexity of project organizations

The CPM Mental Model

The Process Mental Model
The Problems
Lean Developments
BIM Developments
Lean and BIM Synergies
KanBIM
Research Agenda

Construction Industry as a Network

The Real World?

Possible explanations

- Increased **product** complexity – more and more complex building systems....
  - but adding the basic durations for these does not explain the change.
- Increased **process** complexity
- Increased **organization** complexity
- Deficient production systems!
  - Deficient production management - contract management has replaced production management
  - Local optimization – productivity of individual teams. Works against optimization of the whole*

Deficient production systems

... cause **Waste:**

- Workers waiting for information, materials, etc.
- Rework
- Moving
- Work in progress
- Over-production
- Unnecessary processing
- Transfer of materials (double-handling)
- Products that do not meet requirements
Introduction

• Lean Construction
• Building Information Modeling (BIM)

• Both Lean and BIM are deep **process changes**, in thinking and in practices. Both require concerted **long-term efforts**, within **stable business and work environments**

“**Insanity**”:  
*Doing the same thing over and over and expecting a different result*

*Albert Einstein*
Introduction

• Construção enxuta
• Modelo de Informação da Construção (BIM)
• Ambos envolvem mudanças profundas, à nível teórico e prático. Ambos requerem esforços concatenados à longo prazo, no quadro de um ambiente de trabalho e negócios estável

“Insanidade”:
Fazer a mesma coisa repetidamente e esperar um resultado diferente

Albert Einstein
Lean Construction Developments

- Transformation/Flow/Value concepts of production in construction
- Last Planner System™
- Lean Supply Chain Management
- Integrated Project Delivery
The Last Planner System™

Mass Construction

Lean Developments

BIM Developments

Lean and BIM Synergies

KanBIM

Research Agenda

The Problems

LEAN Production

Uniform products and spaces
Smooth flow
Standardized work
Material logistics

MASS Production

Unique products
High-skilled work
Hand-made

CRAFT Production

Ability to cope with customized spaces
Pull flow
Multi-skilled teams
Low WIP

LEAN Construction

Industrialized Construction (Off-site)

Uniform products
Low skilled work
Push flow
Large inventories

Mass Construction (On-site)

Unique products
Low WIP

Pull flow
Multi-skilled teams

CRAFT Construction

Material logistics

BIM Developments
BIM Technology Developments

- **Automated model checking** for code conformance and constructability (e.g. Solibri)
- Major BIM platform vendors are integrating design assessment capabilities (e.g. Robot in Revit Structures).
- Vendors are increasingly providing discipline-specific BIM tools.
- Building product manufacturers are beginning to provide parametric 3D catalogs.
- BIM tools with construction management functions (e.g. Tekla, Synchro, others).
BIM Business Trends

- **Owners are demanding BIM** and changing contract terms to enable its use.
- **New skills and roles** are developing (BIM Manager, PIO).
- The proportion of 'very heavy' BIM users among all respondents grew from 34% in 2008 to 45% in 2009.
- **Corporate-wide uptake by general contractors**. Skanska, Turner, Mortenson all have in-house BIM training for project engineers.
- **Integrated project delivery** (IPD) are receiving wide review and being tested intensively in practice.

Integrated Form of Agreement for Lean Project Delivery (IFoA) developed for Sutter Health
ConsensusDOCS300 (USA) [http://www.consensusdocs.org/](http://www.consensusdocs.org/)
AIA C191-2009 Standard Form Multi-Party Agreement for IPD
Additional BIM Trends

- **Standards** efforts are gathering steam (IFC 2x4, CIS/2, NBIMS in US).
- **Green building** is increasingly demanded by clients.
- BIM and **4D CAD tools** have become common tools in large construction site offices.
- BIM is **encouraging prefabrication** for increasingly complex building sub-assemblies, which can be procured globally.
BIM and Lean Construction

- **Design**
  - Reduce design development cycle time
  - Manage information flows

- **Detailing**
  - Standardized work methods
  - Pull flow of labor

- **Construction**
  - Error free construction
  - Pull flow of information
  - Increased prefabrication and pull of parts

- **Operate and Maintain**
  - Pull flow of labor
  - Maintain information value

**Lean and BIM Synergies**
- BIM and Lean Construction
  - Pull flow of information
  - Design
  - Reduce design development cycle time
  - Manage information flows
  - Detailing
  - Standardized work methods
  - Construction
  - Error free construction
  - Pull flow of information
  - Operate and Maintain
  - Pull flow of labor
  - Maintain information value
Lean Principles

- Reduce variability
- Reduce cycle times
- Reduce batch sizes (strive for single piece flow)
- Increase flexibility
- Select an appropriate production control approach
- Standardize
- Institute continuous improvement
- Use visual management
- Design the production system for flow and value
- Ensure comprehensive requirements capture
- Focus on concept selection
- Ensure requirement flow down
- Verify and validate
- Go and see for yourself
- Decide by consensus, consider all options
- Cultivate an extended network of partners
BIM Functionality

- Visualization of form
- Rapid generation and evaluation of multiple design alternatives
- Maintenance of information and design model integrity
- Automated generation of drawings and documents
- Collaboration in design and construction
- Rapid generation and evaluation of construction plan alternatives
- Online/electronic object-based communication

### Lean - BIM Interaction Matrix

<table>
<thead>
<tr>
<th>BIM Functionality</th>
<th>Lean Principles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visualization of form</td>
<td>Reduce Variability</td>
</tr>
<tr>
<td>1</td>
<td>1,2</td>
</tr>
<tr>
<td>Rapid generation and evaluation of multiple design alternatives</td>
<td>2</td>
</tr>
<tr>
<td>Maintenance of information and design model integrity</td>
<td>6</td>
</tr>
<tr>
<td>Automated generation of drawings and documents</td>
<td>8</td>
</tr>
<tr>
<td>Collaboration in design and construction</td>
<td>9</td>
</tr>
<tr>
<td>Rapid generation and evaluation of multiple construction plan alternatives</td>
<td>11</td>
</tr>
<tr>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td>13</td>
<td>2</td>
</tr>
<tr>
<td>Online/electronic object-based communication</td>
<td>14</td>
</tr>
<tr>
<td>15</td>
<td>18</td>
</tr>
<tr>
<td>16</td>
<td>19</td>
</tr>
<tr>
<td>17</td>
<td>20</td>
</tr>
<tr>
<td>18</td>
<td>21</td>
</tr>
</tbody>
</table>
IPD and BIM

“Although it is possible to achieve IPD without BIM, it is the opinion and recommendation of this study that BIM is essential to efficiently achieve the collaboration required for IPD.”


“We hypothesize that the full potential for improvement of construction projects can only be achieved when their [BIM and lean construction] adoption is integrated, as they are in the IPD approach.”

KanBIM™ - BIM and Lean on site

Kanban

(pull flow control in lean production management)

+ 

BIM

(Building Information Modeling)

= 

KanBIM™

Research goals: to propose, define, develop and test a BIM-enabled system to support production planning and day to day production control on construction sites.
KanBIM™ - BIM and Lean on site

Kanban

(APLICAR CONTROLE DE FLUXO NO GERENCIAMENTO DE PRODUÇÃO ENXUTO)

+ BIM

(MODELO DE INFORMAÇÃO DA CONSTRUÇÃO)

= KanBIM™

Objetivos da pesquisa: Propor, definir, desenvolver e testar um sistema BIM para dar suporte ao planejamento da produção e seu monitoramento diário em canteiros
KanBIM™ Principles

- Flexible changes to work methods
- Facilitate communication/encourage discussion
- Shift optimization from local team to whole project
- Keep weekly plan stable; support formal experimentation
- Visualize process
- Visualize product
- Support WIP reduction/Pull workflow control strategy
  - Pull flow index, implement CONWIP
- Constraint filtering – work/task maturity index
- Support ubiquitous reporting of process status
- Implement Language-Action approach
Princípios do KanBIM™

- Flexibilidade de mudanças nas técnicas de trabalho
- Facilitar a comunicação / incentivar a conversa
- Deslocar o foco da otimização da equipa local para o projeto como um todo
- Manter programação semanal estável; dar suporte a experimentação formal
- Visualizar o processo
- Visualizar o resultado
- Dar suporte a redução de trabalho em andamento (WIP) / aplicar estratégias de controle de fluxo de trabalho – Pull Flow Index, implementar trabalho constante em andamento (CONWIP)
- Limitação da filtragem – índice de maturidade / tarefa
- Dar suporte à elaboração de relatório sobre o estado de cada processo
- Implementar uma abordagem multilíngue
The Last Planner System™

**KanBIM™ – Work flow**

1. **Prepare Master Plan**
   - Construction Planner
   - Section/zone managers
   - Trade managers

2. **Prepare Look Ahead Plan**
   - Construction Planner
   - Section/zone managers
   - Trade managers

3. **Compile and Detail Tasks**
   - Trade manager
   - Trade crew leader

4. **Coordinate & Commit to Weekly Work Plan**
   - Construction Planner
   - Section/zone managers
   - Trade managers
   - Trade crew leaders
   - Health & Safety
   - Logistics Manager

5. **Task in Progress**
   - Trade crew leader

6. **Manage Logistics**
   - Logistics Manager

7. **Report Task Completion**
   - Trade crew leader

8. **Stop Task**
   - Trade crew leader

9. **Negotiate proposed plan**
   - Construction Planner
   - Section/zone managers
   - Health & Safety

10. **Inspect Work and Task Completion**
    - Site Engineers
    - Inspector
    - Section/zone managers

**Daily Work Flow**

*Commit, Execute, Report*

---

Master Planning with BIM
Compile and Detail Tasks
Negotiating the Weekly Work Plan
<table>
<thead>
<tr>
<th>Space</th>
<th>Monday</th>
<th>Tuesday</th>
<th>Wednesday</th>
<th>Thursday</th>
<th>Friday</th>
<th>Contingency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basement 1</td>
<td></td>
<td>Complete to ceiling Basement 1</td>
<td>Duct installation in drywalls West side</td>
<td>Pipe installation in drywalls West side</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1,000 m²</td>
<td></td>
<td></td>
<td>Basement 1</td>
<td>Basement 1</td>
<td>Basement 1</td>
<td>Close openings above HVAC Zone 1 Fire fighting pump room</td>
</tr>
<tr>
<td>Basement 2</td>
<td></td>
<td>Partitions Basement 2</td>
<td>Complete to ceiling West side Basement 1</td>
<td>Install main lines Basement 2 Fire fighting pump room</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1,500 m²</td>
<td></td>
<td></td>
<td>Basement 2</td>
<td>Basement 2</td>
<td>Basement 2</td>
<td></td>
</tr>
<tr>
<td>Basement 3</td>
<td></td>
<td></td>
<td>Complete to ceiling Basement 2</td>
<td>Install main lines Basement 2 Fire fighting pump room</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1,500 m²</td>
<td></td>
<td></td>
<td>Basement 3</td>
<td>Basement 3</td>
<td>Basement 3</td>
<td></td>
</tr>
<tr>
<td>Floor 2</td>
<td>Install main lines Basement 3 Fire fighting pump room</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>600 m²</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Floor 3</td>
<td>Sprinkler pipes Floor 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>600 m²</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Floor 4</td>
<td>Sprinkler pipes Floor 4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>600 m²</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Floor 5</td>
<td>Effect Hollowcore Floor 5 Grids A1 to A8</td>
<td>Effect Hollowcore Floor 5 Grids A3 to A8</td>
<td>Prepare and pour topping Floor 5 Grids A1 to D8</td>
<td>Sprinkler pipes Floor 5 Grids A1 to D8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>600 m²</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Floor 6</td>
<td>Effect Hollowcore Floor 6 Grids E5 to E10</td>
<td>Effect Hollowcore Floor 6 Grids E5 to E10</td>
<td>Estate columns Floor 6 Grids E5 to E10</td>
<td>Estate columns Floor 6 Grids E5 to E10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>200 m²</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Main Lobby</td>
<td>Framing for false ceiling Entrance floor Lobby</td>
<td>Main distribution board – Wiring Entrance floor Lobby</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>150 m²</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

© Copyright 2011 Rafael Sacks

Civil and Environmental Engineering
Technion - Israel Institute of Technology
Visualizing Product Info and Process Status
Visualizing Product Info and Process Status
The Problems

Lean Developments

BIM Developments

Lean and BIM Synergies

KanBIM Research Agenda

Visualizing Product Info and Process Status
Process Status Visualization

- Line outer walls: STOP
- Sprinklers Apt. 31: Overdue 23.02.2011
- Electric rough-in Apt. 66:
- Flooring Apt. 49: ✔️
- Electric rough-in Apt. 52: 🔴
The Problems

Lean Developments

BIM Developments

Lean and BIM Synergies

KanBIM Research Agenda

Monitoring Feedback Loop

[Image of a software interface showing a KanBIM task management system with options for starting, committing, canceling, or stopping tasks, along with reasons for stopping such as preceding activities not finished, missing materials, unavailable equipment, and others.]
Experimental Trials on site
Deployment on site
Weekly work planning
Deployment on site for the second and third observation periods
### Summary of Observation Results

<table>
<thead>
<tr>
<th>Measure</th>
<th>Control</th>
<th>Familiarization</th>
<th>Experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent Plan Complete (PPC)</td>
<td>33%</td>
<td>47%</td>
<td>62%</td>
</tr>
<tr>
<td>Labour Stability Index (LSI)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lost work potential hours/total hours planned)</td>
<td>184/421</td>
<td>125/446</td>
<td>613/1,483</td>
</tr>
<tr>
<td>Value-adding and supporting work hours/total planned hours</td>
<td>50%</td>
<td>63%</td>
<td>48%</td>
</tr>
</tbody>
</table>
Summary of Observation Results

Site personnel’s experience with the system was positive:

• Improved ability to visualize the process itself
• Reduced wasted time spent ‘looking’ for work
• Facilitated well-informed discussion and negotiation between crews concerning coordination of their work

With this system, I could manage twice as many apartments

With KanBIM on the web, I could plan my crew sizes better and have less wasted time

Avi, Drywall subcontractor

Viktor, Site Supervisor (GC)
A relação do operários com sistema foi positiva
• Melhor visualização do processo com um todo
• Redução do tempo perdido procurando trabalho
• Facilitação da informação pertinente à conversa e negociação entre as equipes envolvendo a coordenação do seu trabalho

With KanBIM on the web, I could plan my crew sizes better and have less wasted time

Avi, Drywall subcontractor

With this system, I could manage twice as many apartments

Viktor, Site Supervisor (GC)
KanBIM

• See:

http://www.youtube.com/watch?v=1rKfenvLTiY

http://www.youtube.com/watch?v=eLfFLjKUcDk
The Problems

Research Agenda

Further research is needed to test the facility of planning and control with the KanBIM™ system, which requires online access to material, equipment and other management information systems.

If we wish to see information used throughout construction supply chains, we need to figure out:

• How can/do contracting arrangements engender the collaboration (the virtual companies) needed for virtual design and construction? Economic game theory....

• What information architectures are needed to support delivery of up-to-date process and product information on the job site?
Virtual Construction Lab
Virtual Construction Lab
Summary

• BIM and Lean synergy

• BIM can support production control:
  – Deliver **Product** information to workers – so they can **do the work right**
  – Deliver **Process** Information to workers – so they can **do the right work**
Conclusão

• Sinergia entre BIM e construção enxuta

• BIM pode proporcionar suporte para controle de produção:
  – Fornecendo informações sobre os materiais aos operários – de maneira a que eles trabalhem da maneira correta
  – Fornecendo informações sobre os processos aos operários de maneira a que eles façam o trabalho que devem
Thank you....

Any questions?

Building Information Modeling Support for Production Control On Site

Assoc. Professor Rafael Sacks

Virtual Construction Lab
Civil and Environmental Engineering
Technion - Israel Institute of Technology

© Copyright 2011 Rafael Sacks
Obrigado pela atenção...

Perguntas?

BIM - Modelo de Informação da Construção
Suporte para controle de produção in situ

Assoc. Professor Rafael Sacks

Virtual Construction Lab
Civil and Environmental Engineering
Technion - Israel Institute of Technology