Teaching BIM and Lean Construction at the University of Huddersfield and at Aalto University

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Contents

• What is the issue?
• Prior research
• Aalto University
• University of Huddersfield
• Conclusion
WHAT IS THE ISSUE?
BIM: the question is about product representation

• Gaspard Monge created descriptive geometry in the 1760’s – technical drawings have been based on that since then
• In Building Information Modelling, product representation is based on objects (in computer science sense) which model three dimensions and are parametric
• Thus, it is a change *merely* in product representation – or is it?
Actually...

- At the outset, the power of BIM was considerably underestimated
  - Saving of manual labour eliminating duplicate inputting of data was originally a major driver
  - Practitioners have tended to find new uses when getting familiar with BIM
  - Inefficiencies of the traditional process is revealed
  - Synergy with parallel development initiatives, like lean and sustainability
What is lean? What is not lean?

Mainstream thinking on management and engineering

• The central and noble task of managers and engineers is to find the best possible (optimal) plan or design
• It is the duty of others to realize the plan or design
• Leads to the need for organizational control

Lean thinking

• Besides enabling the finding of the best possible plan or design, managers and engineers should focus on reducing the gap between the intended/ideal and the achieved oddslot (this gap equals waste)
• There will always be waste (unnecessary use of resources)
• Leads to the need for learning and improvement

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Simply...

Mainstream thinking on management and production  Lean thinking

Idea → World  Idea ← World
Scientific engineering

- Phenomenon
- Physical laws
- Context
- Artefact

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Economics does not recognize waste!

• The mainstream economic doctrine includes the assumption of optimal productive efficiency of firms. For example, in his book on construction economics, Myers (2004) says:

  “In any free market economy businesses will never waste inputs. A business will not use 10 units of capital, 10 units of labour, and 10 units of land when it could produce the same amount of output with only 8 units of capital, 7 units of labour, and 9 units of land.”

Toyota production system

1. Routinized manufacturing capability
   • static & routine
2. Routinized learning capability
   • *dynamic* & routine
3. Evolutionary learning capability
   • *dynamic* & non-routine

(Fujimoto 1999)
Building Information Modelling (BIM) and Lean

• Building information modelling and lean construction have existed as two different initiatives, with distinct communities and interests

• In the last 7+ years, the insight has gained strength, first among pioneering practitioners and then among academic, that these two initiatives are highly synergistic

Table 3. Interaction Matrix of Lean Principles and BIM Functionalities

| BIM Functionality | Lean principles | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T | U | V | W | X |
| Visualization of form | 1 1.2 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Rapid generation of design alternatives | 2 1 22 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Reuse of model data for predictive analyses | 3 9 9 22 51 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Maintenance of information and design model integrity | 4 10 12 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Automated generation of drawings and documents | 5 1.2 1 12 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Collaboration in design and construction | 6 11 11 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Rapid generation and evaluation of multiple construction plan alternatives | 7 12 12 22 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Online/electronic object-based communication | 8 11 22 (52) 53 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Note: Numbers in the cells are indexes to the cell content explanations provided in Table 4 and numbers in brackets represent negative interactions.
The lean principles that have the highest concentration of interactions with BIM features

- “Get quality right the first time (reduce product variability),”

- “Focus on improving upstream flow variability (reduce production variability)”

- “Reduce production cycle durations”.
BIM functionalities that have the highest concentrations of interactions with lean principles

• “Aesthetic and functional evaluation”,
• “Multi-user viewing of merged or separate multi-discipline models”,
• “4D visualization of construction schedules”
• “Online communication of product and process information”.
Benefits need to be nurtured!

• Consider the significant shortening of cycle time that is commonly achieved when quantity take-off is extracted from a building model, as compared with traditional measurements from drawings. This can be exploited to improve the value generated through iterative design refinement, but only if managers recognize a) that the shortened cycle time shifts the bottleneck in the process to other activities, and b) that the overall design management approach can be re-aligned to bring designers and estimators to work together. Thus cycle-time is reduced by BIM whether project participants are aware of it or not, but comprehensive benefits can only be achieved when its meaning is perceived clearly.
1 BIM contributes directly to lean goals

- Clash detection
- Visualisation of coordinated/synchronized models
2 BIM enables lean processes and contributes indirectly to lean goals

- Collaborative design
- 4 D planning in support of first run studies for construction
- Generally: providing common ground
3 Auxiliary information systems, enabled by BIM, contribute directly and indirectly to lean goals

• BIM based cost models
  – Designing to cost, rather than costing a design

• Carbon footprint and other sustainability models
4 Lean processes facilitate the adoption and use of BIM

• Lean construction context, especially
  – discipline and predictability,
  – collaboration and experimentation, as well as
  – continuous improvement

• facilitate the implementation of BIM.
Managerial implications

1. Careful, comprehensive and systematic building of the information model
2. Explore how lean processes can be supported through BIM functionalities
3. Explore which auxiliary models useful and whether lean processes are needed
4. Implement lean prior and parallel to BIM
What lean and BIM can achieve: case hospital construction in California

- Due to tightening earthquake resistance requirements, a big number of hospitals in California have been and are being (re)constructed
- An innovation ecosystem of advanced clients, contractors, architects, lawyers, universities and software vendors present in California
- Especially, lean knowledge centre at Berkeley and BIM knowledge centre at Stanford
New solutions

- A synthesis of advances on several fronts
  - Lean design and production management
  - Building Information Modelling
  - New contractual models that promote collaboration (Integrated Form of Agreement)
  - New organizational models that promote collaboration (Integrated Project Delivery, IPD)
  - Structured way of continuous value engineering: Target Value Design
Lean Project Delivery System

- Cross functional organization
- Joint and open decision making process
- Big Room

- Last Planner System
- BIM
- Target Value Design
- Choosing By Advantages
- Set Based Design

- Multi Party contracts
- Pain and Gain Sharing Mechanism

The LCI triangle model (Thomsen et al., 2009)
Sutter Health’s Eden Medical Center Project: Cost trajectory

Legend:
- **Red**: Total project actual cost of work inclusive of escalation estimate and warranty allowance; this shows the typical trajectory of expected cost during design
- **Green**: Owner’s budget (not part of the IFOA (Integrated Form of Agreement) contract), inclusive of Owner’s contingency
- **Orange**: IFOA Team’s Contingency
- **Blue**: IFOA Team’s Shared Profit Pool, pool members got 80% of their potential profit

Courtesy of Sutter Health
Outcomes

• Cost and schedule certainty
• Project costs decrease during design and construction
• Reduction of project costs from audited market costs by 15 – 20 – 30 % - this percentage tends to increase along with increased experience with the model
PRIOR RESEARCH

(THIS SECTION BASED ON MATERIALS BY ERGO PIKAS)
Research by Ergo Pikas


Many universities are struggling:

- No common understanding of BIM education
- No systematic approach
- No clear understanding of BIM content and skills required by industry
- Not clear, which teaching strategies, principles and methods to use
BIM in education and construction management programs

Commonly accepted BIM education approaches/elements:

• Integration of BIM component throughout all the years of AEC education: Metaphor for teaching BIM is masonry (Clevenger et al.): bottom up and piece by piece

• Division of BIM education (Gordon et al., Becerik-Gerber et al. 2011, Barison and Santos 2010a and 2010b):
  1. BIM fundamentals and concepts
  2. BIM methodologies and techniques
  3. BIM for specific fields and analysis (integration to existing courses and projects)
  4. Advanced BIM topics: collaboration, integration of disciplines and fields of engineering, etc.
BIM in education

Barison and Santos (2010a) studied 103 syllabuses/papers and divided BIM courses into eight categories:

1. Digital graphical representation (e.g. Sacks and Barak, 2010, Wong et al., 2011);
2. Workshop;
3. Design studio (Porschke et al., 2010);
4. Specific BIM tool courses;
5. Building technology;
6. Construction management (Peterson et al., 2011);
7. Thesis project (Kymrell 2008); and
8. Internship
Conclusions

• The scope of a BIM education depends on the context and the objectives of a university. No construction management program can get by not introducing BIM at all.

• BIM can be taught in many ways, important is the continuity.

• BIM can support students learning process of many fields and topics

• BIM education has to be approached from a systems point of view (as it is a whole life cycle tool)

• Research confirmed that BIM technology enhances engineering education by providing realistic models of real life problems
AALTO UNIVERSITY

(THESE SECTION BASED ON MATERIALS BY DR. VISHAL SINGH)
Context

• Formerly a 4.5 year Master of Engineering course
• Now 3 year Bachelor and 2 year Masters course, to start in full in 2016
  – Bachelor course not universally seen as a self-standing option
• Very small fee, the universities publicly-funded
• Finland early adopter of BIM
Aalto BIM Initiative: multidisciplinary group

BIM and design for X
Prefabrication, Safety, Maintenance...

BIM ecosystem
Macro-ecosystem (Market, Policies, etc)

BIM for Lean
Production management Field Computing...

BIM for FM
Operations, Services, Maintenance...

BIM for district level

BIM for IOT
Monitoring, Control, Tracking...

Energy management

BIM and IOT
Monitoring, Control, Tracking...

BIM and IOT
Monitoring, Control, Tracking...

BIM and IOT
Monitoring, Control, Tracking...

BIM as an enable

Virtually design and construct
Design efficiently!

Life cycle management
Product people-process interactions

Teaching & practice

Smart built environments
Maintain as required

Improve values of buildings in use?
Finnish BIM network: Partial view

Need education

Provide education

Educational Content

Facilitators

Tekes

YIT

SWECO

SKANSKA

NCC

Fira

Aalto University

Helsinki Metropolia University of Applied Sciences

Tampere University of Technology

RamBoll

FCG

VTT

buildingSMART Finland

gravicon

Sennatti

Urban Mill

TEKLA

VIANOVA

MagiCAD

Granlund

A-INSINÖÖRIT

RYM Oy

Trimble
BuildingSmart Finland education industry group

- Steps
  - Publications: e-books
  - InfraBIM competence development
  - Apprenticeship training of high-skilled
  - BIM-employment (AaltoPRO)

Established 2013
InfraBIM Apprenticeship Education: 2014

• Practical, close industry collaboration
• Public funded (60 students)
• Combined effort of five educational institutes
  • **UAS:** Metropolia, Tampere
  • **Universities:** Aalto, Tampere, Oulu
BIM Education at Aalto University

• Bachelors, Masters courses
  – BIM in construction (construction management and processes)
  – Computational Modelling in Engineering
  – Advanced Construction Project Management

• Bachelors, Masters, Doctoral theses

• BIM workshops [short courses, including CPD]
  – Also Aalto Pro
  – Aalto BuildingSmart BIM Breakfasts
Teaching: desirable scenario

Industry engagement!!
Research and development opportunity in each interface!
Pilot studies and feedback

Courses from other disciplines
Approaches to BIM education at Aalto University

• Integration
  - Different aspects of civil engineering
  - Practitioners and industry experts in education
  - Research and teaching

• Groupwork and Project-based

• Case-based learning

• Flipped classroom

• Develop learning solutions and methods in the process!
Case study (Term 1)/ Project (Term 2)

WBS: explain why these groups?

Arch. Design Team
- Group 1
  - 2X

Str. Design Team
- Group 2

HVAC Team
- Group 3

PM/CM Team
- Group 4

FM/ Maint’nce Team
- Group 5

CAD/ IT team
- Group 6

Group 1: Architectural design, Material,
Group 2: Structural mechanics, Building materials
Group 3: Building physics, HVAC, nZero
Group 4: CME,
Group 5: BES, FM, maintenance and refurbishment
Group 6: BIM, computational modelling
Group 7: (?) Special requirements
Context

• UK University landscape:
  – high fees
  – share of overseas students considerable
  – BSc seen as an independent, complete degree
  – One year (or longer) MSc courses

• Construction management and BIM new topics in the School of Art, Design and Architecture
Master courses starting 2015

• MSc Advanced Project Management in Construction; Core taught modules
  – Lean and BIM in construction projects (30 credits) (term 1)
  – Advanced Procurement in Construction (30 credits) (term 1)
  – Construction Project Management: Planning and Control (30 credits) (term 2)

• MSc Design Integration and BIM; Core taught Modules:
  – BIM at the industry level: needs and strategies (30 credits) term 1
  – Lean and BIM in construction projects (30 credits) term 1
  – BIM at the project level: collaborative approaches (30 credits) term 2
INSTEAD OF A CONCLUSION...
Instead of a conclusion

• Although BIM seems a powerful tool that finally seems to fulfill the hopes associated to the use of IT in construction, it has to be remembered that it is a tool only, and

• crucial cognitive/social/manual skills have still to be cultivated in students
  – Sketching by hand
  – Problem solving
  – Collaborative working
  – Persuasion
  – Continuous improvement.