TUM IAS Siemens Workshop Digital Twins

Construction Tech

Adoption of Innovative Technologies in Construction

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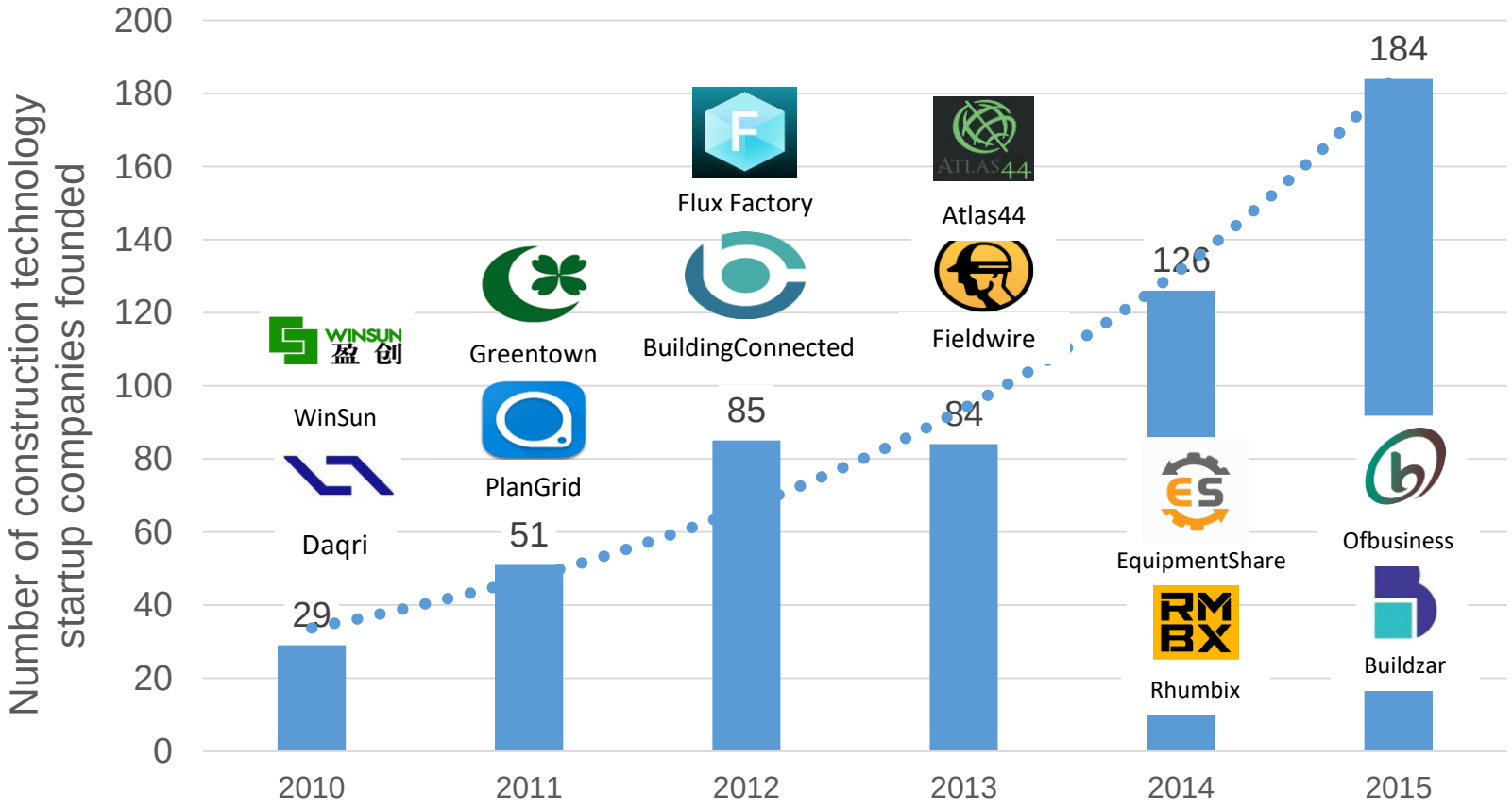
Motivation

In this decade, we are witnesses to a surge in innovation in construction. Some of that innovation has emerged within existing architectural, engineering and construction companies, and some from established software vendors, but the most exciting developments are in Construction Tech startup companies.

Most of these build directly on the theoretical and technological foundations provided by Lean Construction thinking and BIM technology. The seeds of some of the most promising innovations can be traced back to the fundamental and applied research in academia and in industry that make them possible.

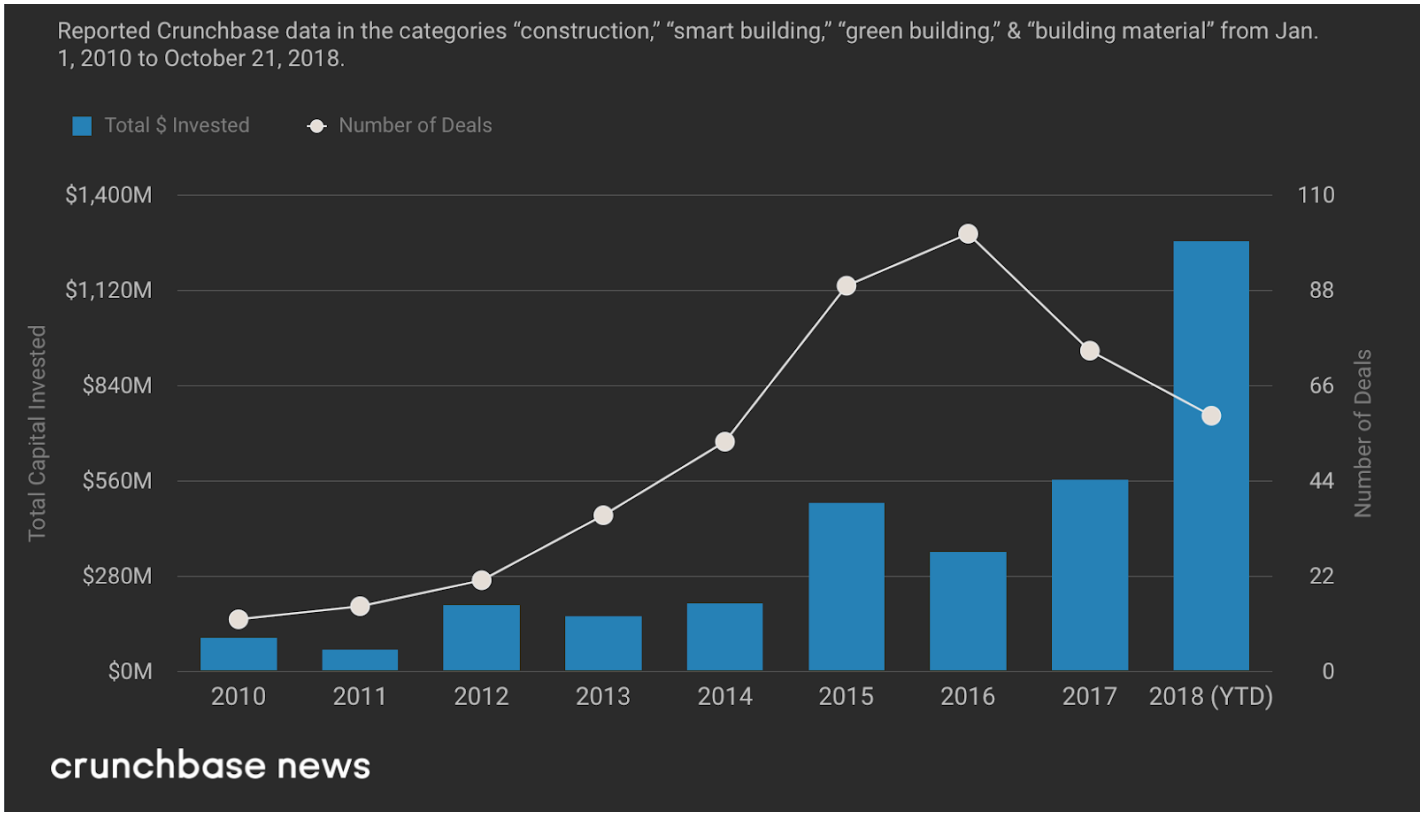
Can we learn anything from Construction Tech adoption and extend it to Digital Twin adoption?

Construction Tech startup companies



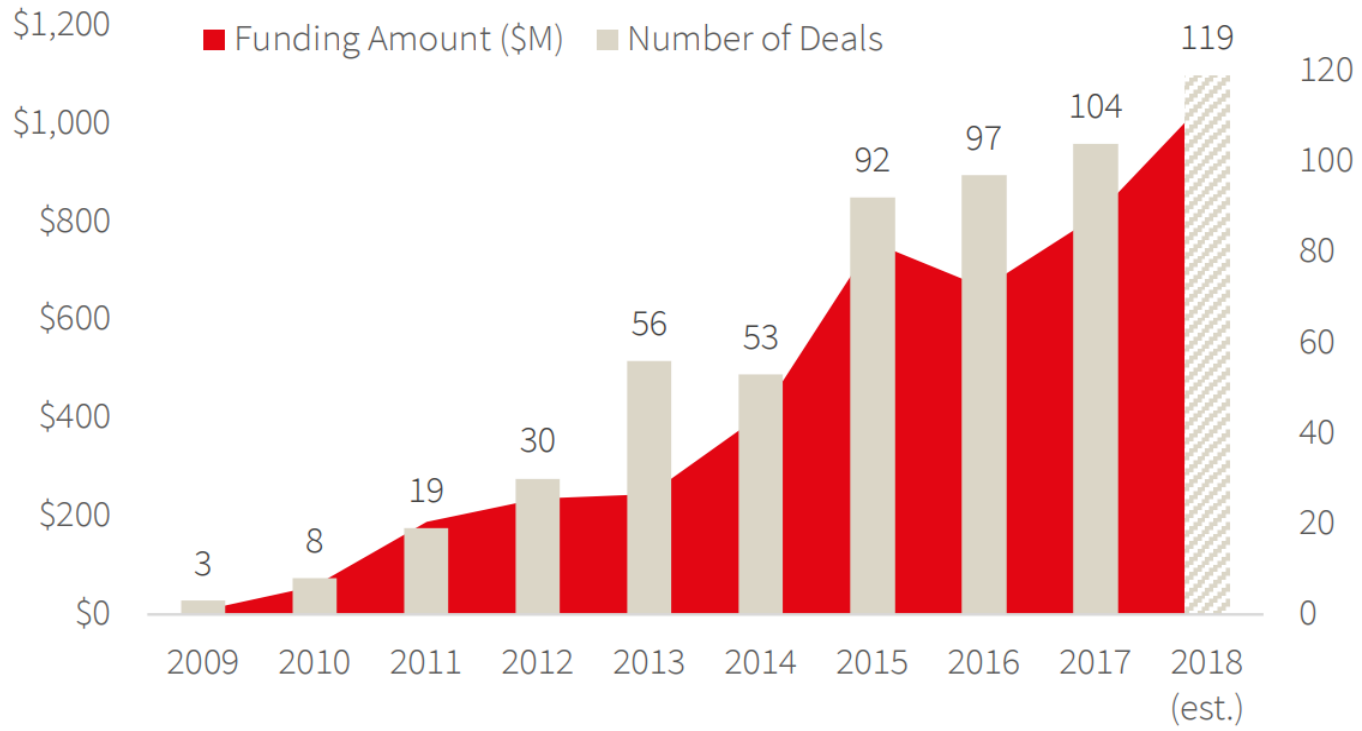
Data source: Tracxn Technologies Private Limited.

Construction Tech startup investment



[Construction Tech Sector Funding Rises As Prescient Raises $50M More]
Mary Ann Azevedo, Crunchbase News, October 24, 2018

Construction Tech startup investment



Source: CB Insights, JLL Research

From Jones Lang LaSalle IP, Inc.
Research Report Americas
2018 The State of Construction Technology
Kylie Andersen, Thomas Forr

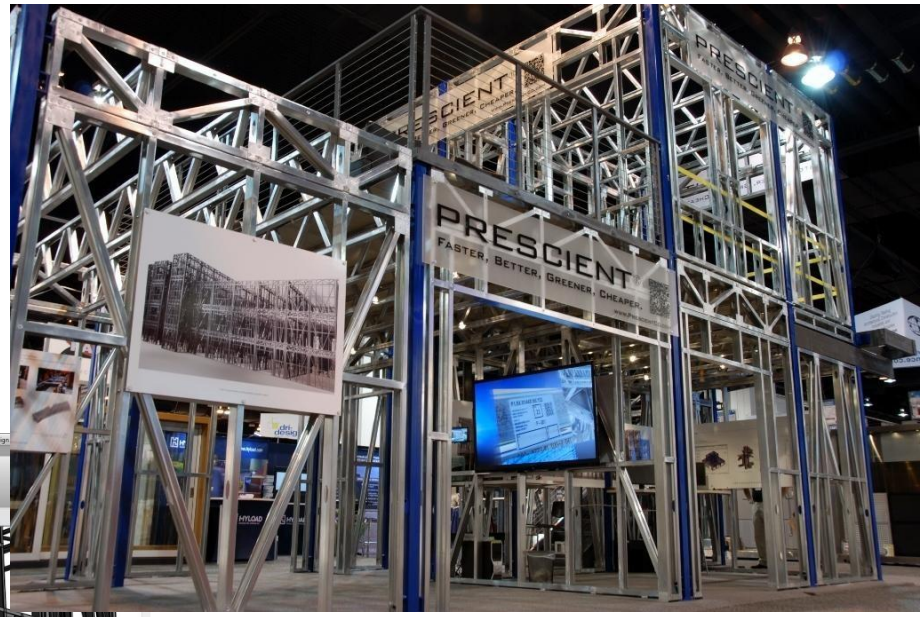
Construction Tech Funding

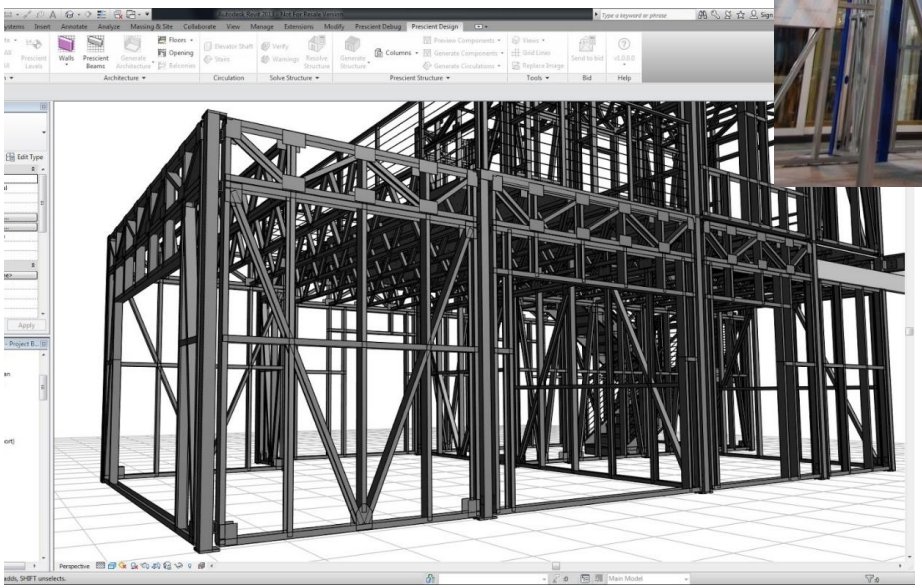
crunchbase news TOPICS ABOUT VC REPORTS

VENTURE

Construction Tech Sector Funding Rises As Prescient Raises $50M More

Mary Ann Azevedo October 24, 2018





PRESCIENT®
Revolutionize the Building Environment

BIM Handbook, 3rd Edition
Chapter 7

Construction Tech

High Tech Industry

Low Tech Industry

No Tech Industry ?

Paths of Innovation

- Within design and construction companies
- Within software companies
- Startup companies…
- ….. acquisitions (Revit, PlanGrid, etc.)

Construction Tech

….from research to startup

Robotics in Construction

ROBOTICS IN BUILDING CONSTRUCTION

By Abraham Warszawski[1] and Dwight A. Sangrey[2]

ABSTRACT: The paper examines possible applications of robotics to building construction. First, the main features of industrial robots and their applications are described. Then, building activities are separated into basic components, and the performance requirements from a robot, necessary for their execution, are specified. A conceptual description of four types of construction robots is derived from these performance requirements. An adaptation of the construction process and of building components for efficient application of these robots is then analyzed. Some special problems associated with robotization of construction process are also explored.

J. Constr. Eng. Manage., 1985, 111(3): 260-280

Robotics in Construction

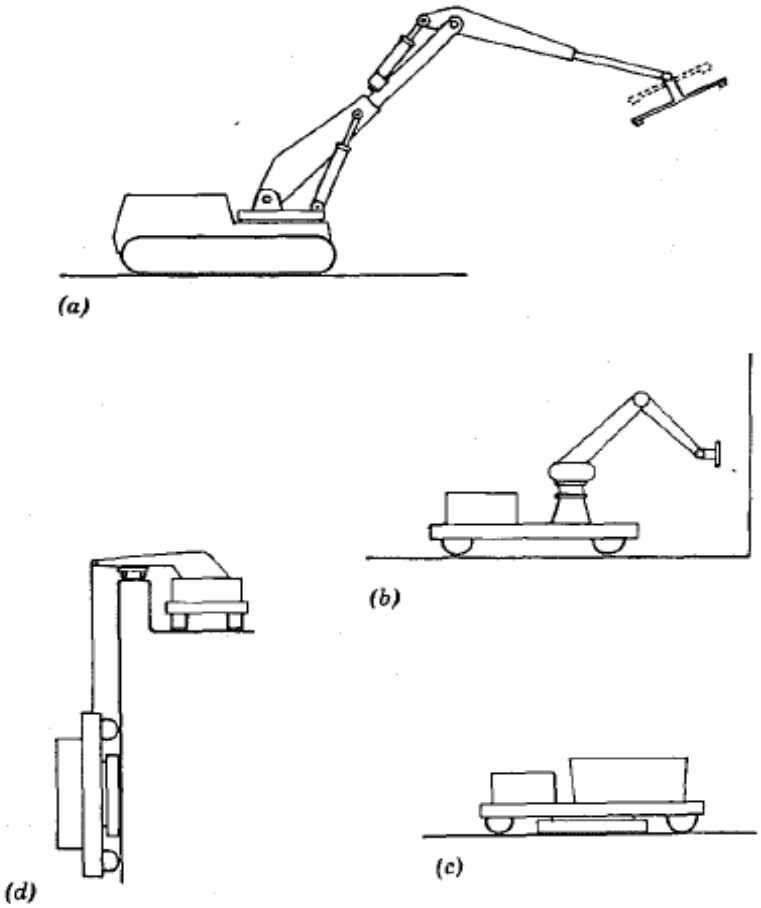


FIG. 3.—Construction Robots: (*a*) Assembly Robot; (*b*) General Purpose Robot; (c) Floor Finishing Robot; (*d*) Exterior Wall Robot

Warszawski and Sangrey, 1985

1993 TAMIR

Technion Autonomous Multi-purpose Interior Finishing Robot

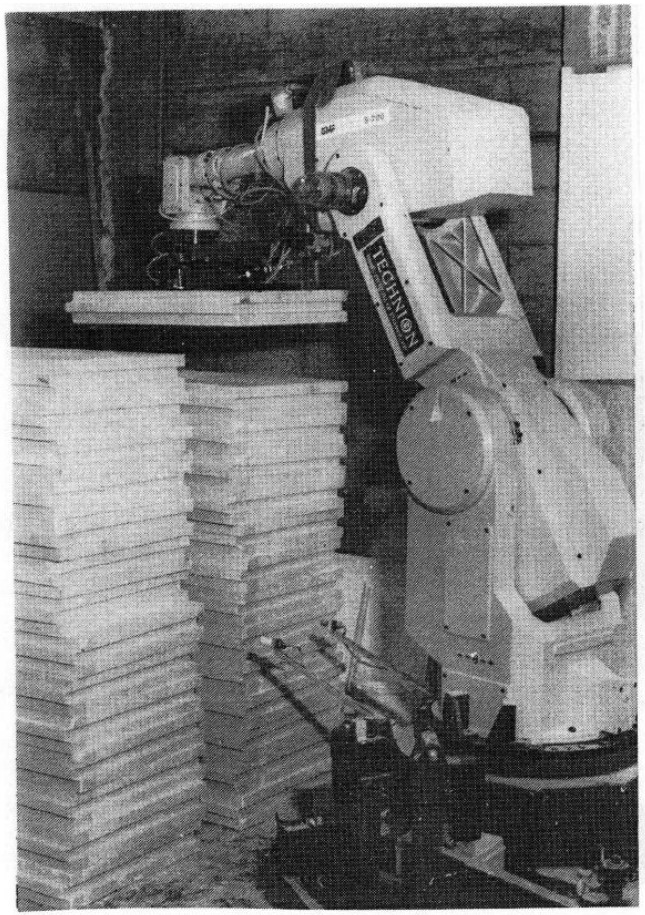


Fig. 1: Picking a block from the stack.

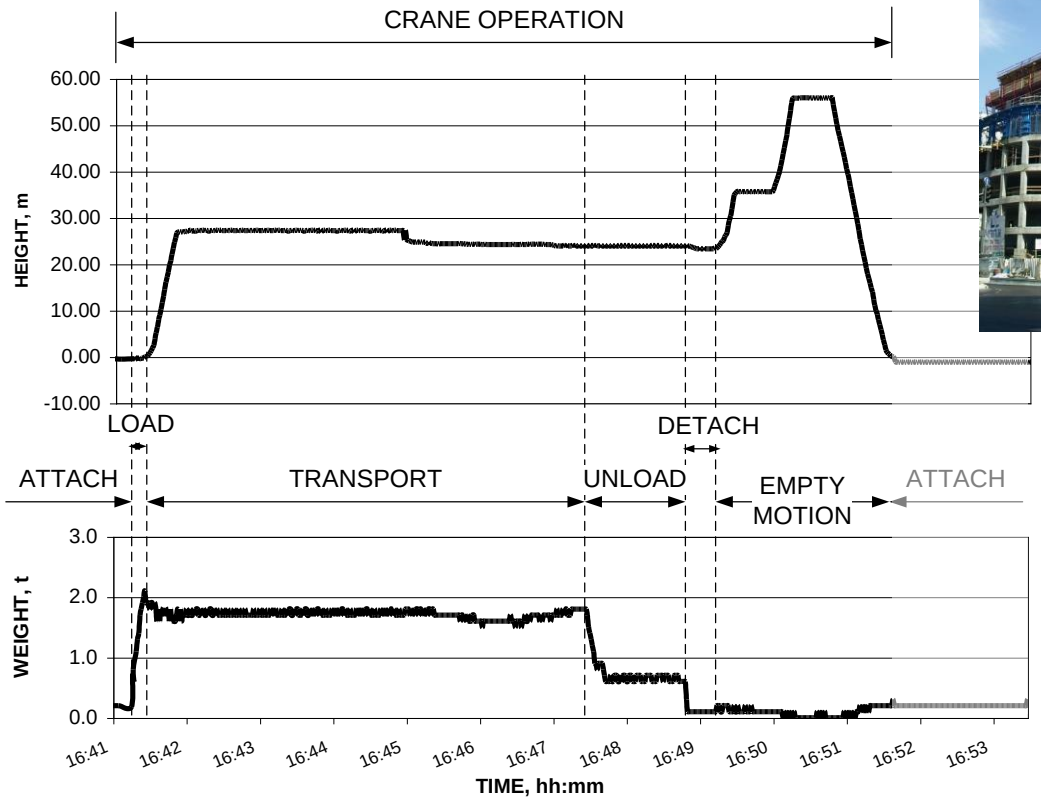
Fig. 2: A complete wall segment.

Interior Finishing Building Robot "TAMIR"
*Yehiel Rosenfeld, Abraham Warszawski, Uri Zajicek*Pages 345-354 (1991 Proceedings of the 8th ISARC, Stuttgart, Germany)

2018 OKIBO


OKIBO

2006



Sacks, R., Navon, R., and Brodetskaia, I., (2006). 'Interpretation of Automatically Monitored Equipment Data for Project Control', Journal of Computing in Civil Engineering, Vol. 20 No. 2 pp. 111-120.

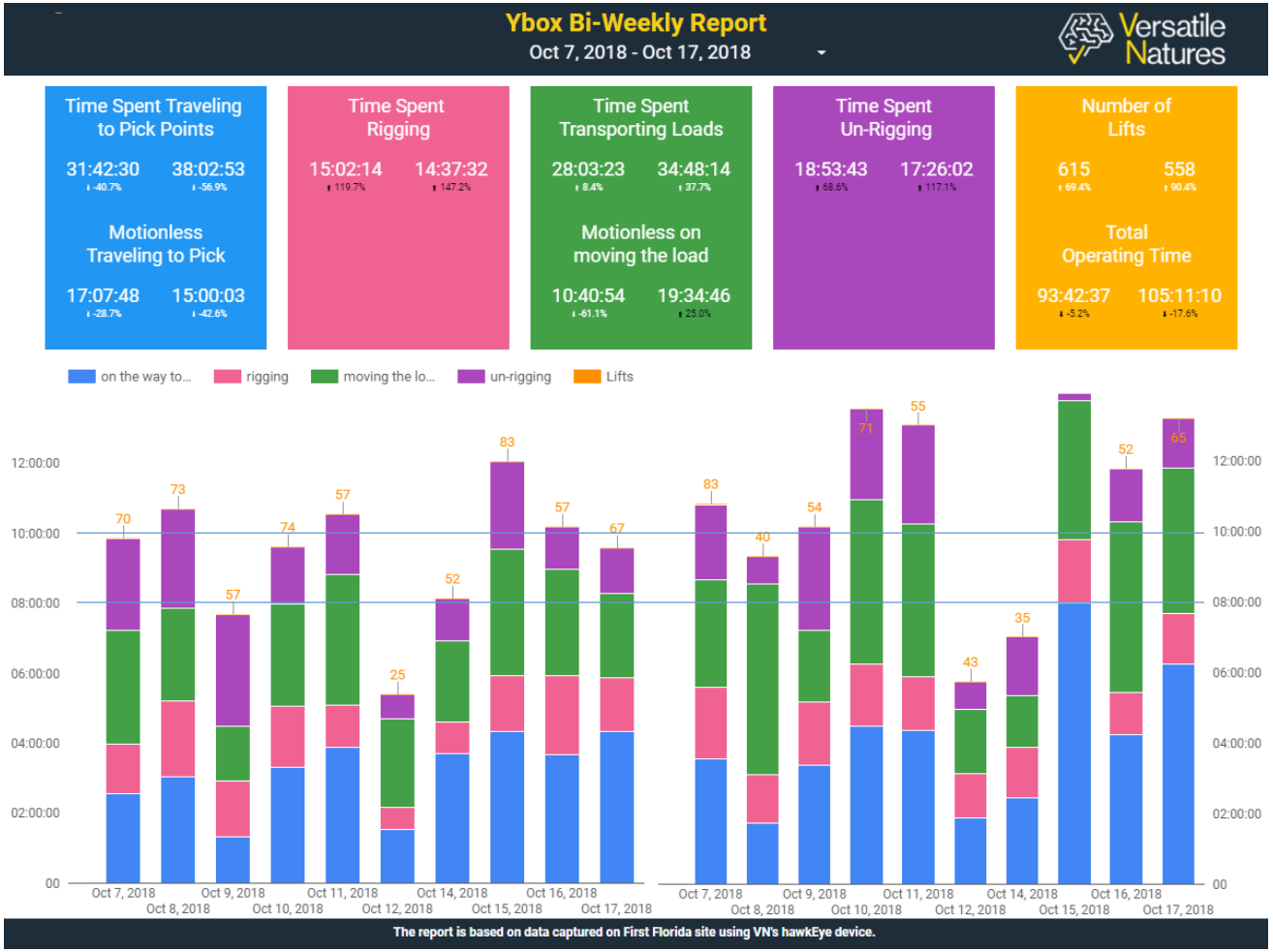
2018

- Gathering sensor data in real time
- Extracting real world events
- Creating a digital representation of the process

2018


Versatile Natures
YBOX / Crane 1
93 (93 tagged) cycles 56305 events 2105 real-world events
nonproductive
14:17:47
14:17:57
14:18:07
Selected
14:17:57 1540725477
Cycle 11280 (333 KG)
Reinforcement - Straight rebars
Step IV
416 KG 30.4 M 97.4 M
Load Type: Reinforcement - Straight
Category: Reinforcement
Start Step 4
End Step 4
Create Cycle
Create Cycle To
Save
Cycles
Reinforcments Welded Cage
Reinforcement – Straight rebars
Formworks
Formworks Unkonwn
Formworks
Formworks
Formworks Formworks
Reinforcments Welded Cage
Formworks
Weight
66 KG
BMP Alt
27.56 M
GPS Alt
0.00 M
Movement
0.00 M

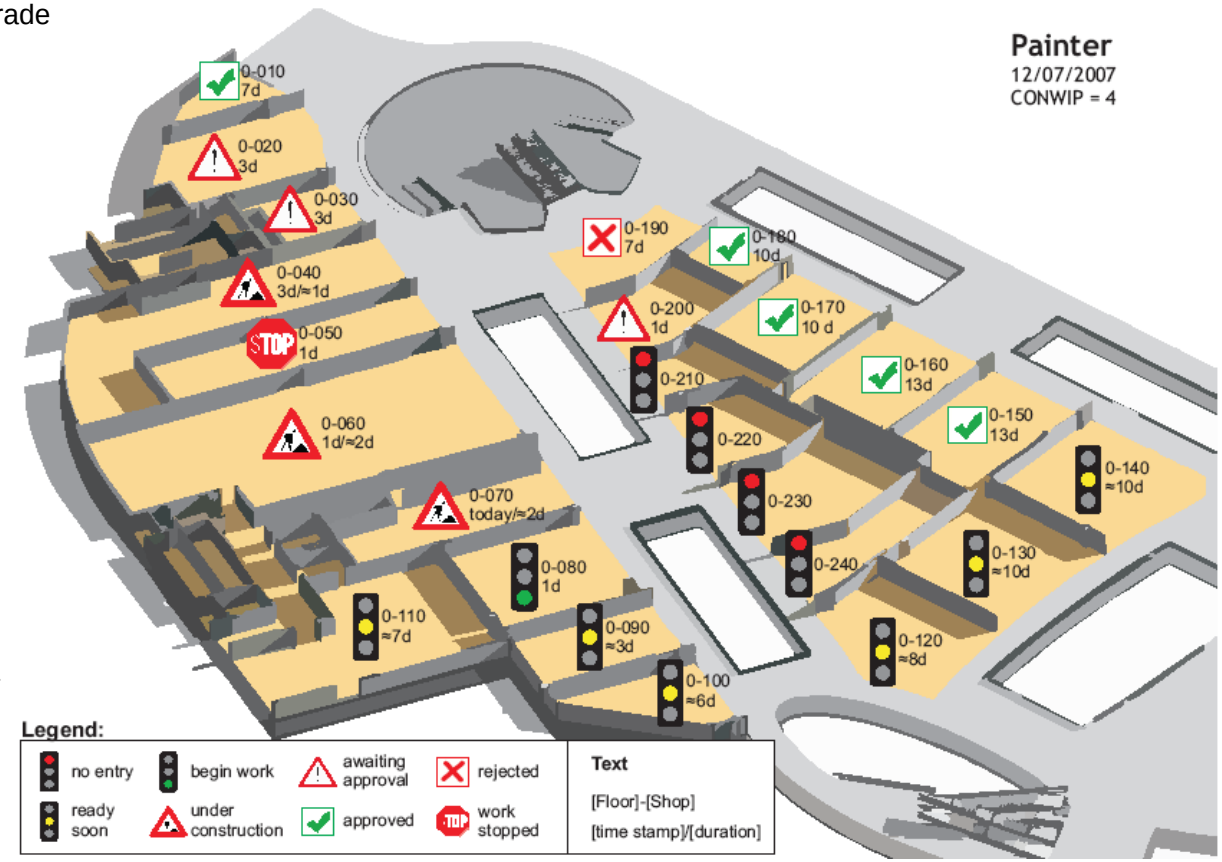
2018


Ybox Bi-Weekly Report
Oct 7, 2018 - Oct 17, 2018
Versatile Natures
Time Spent Traveling to Pick Points
31:42:30
38:02:53
Motionless Traveling to Pick
17:07:48
15:00:03
Time Spent Rigging
15:02:14
14:37:32
Time Spent Transporting Loads
28:03:23
34:48:14
Motionless on moving the load
10:40:54
19:34:46
Time Spent Un-Rigging
18:53:43
17:26:02
Number of Lifts
615
558
Total Operating Time
93:42:37
105:11:10
on the way to...
rigging
moving the lo...
un-rigging
Lifts
12:00:00
10:00:00
08:00:00
06:00:00
04:00:00
02:00:00
00
70
73
57
74
57
25
52
83
57
67
83
40
54
71
55
43
35
52
65
Oct 7, 2018
Oct 8, 2018
Oct 9, 2018
Oct 10, 2018
Oct 11, 2018
Oct 12, 2018
Oct 14, 2018
Oct 15, 2018
Oct 16, 2018
Oct 17, 2018
The report is based on data captured on First Florida site using VN's hawkEye device.

2008 Lean and BIM Production Control

2008

Proposed 3D visualization of past, present and future work status for a trade



Sacks, R., Treckmann, M., and Rozenfeld, O., (2009). '[Visualization of Work Flow to Support Lean Construction]', Journal of Construction Engineering and Management, Vol. 135 No. 12 pp. 1307-1315.

2009 KanBIM

Aim:

To propose, define, develop and test a BIM-enabled system to support production planning and day to day production control on construction sites.

Kanban

(Pull flow control in lean production management)

+

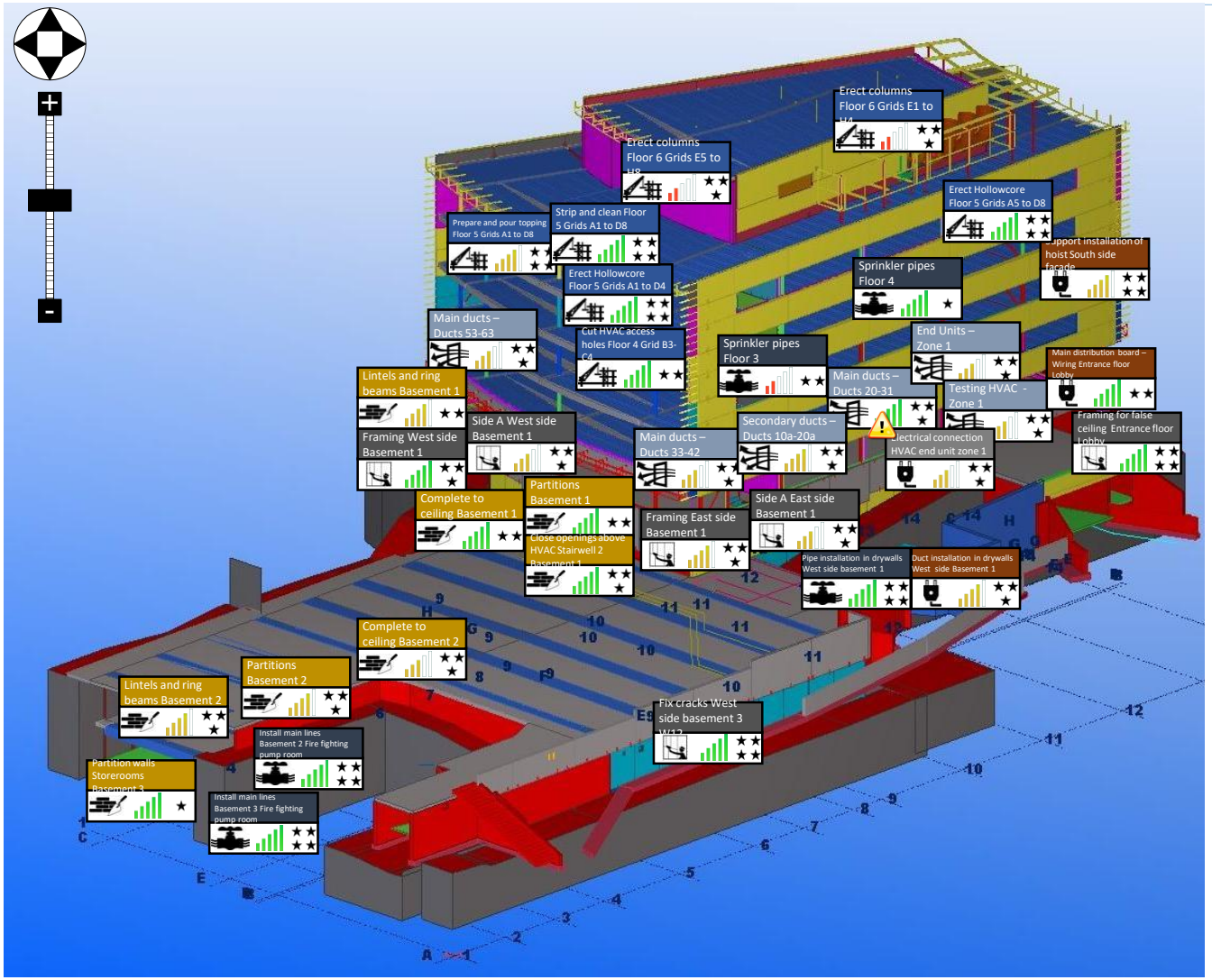
BIM

(Building Information Modeling)

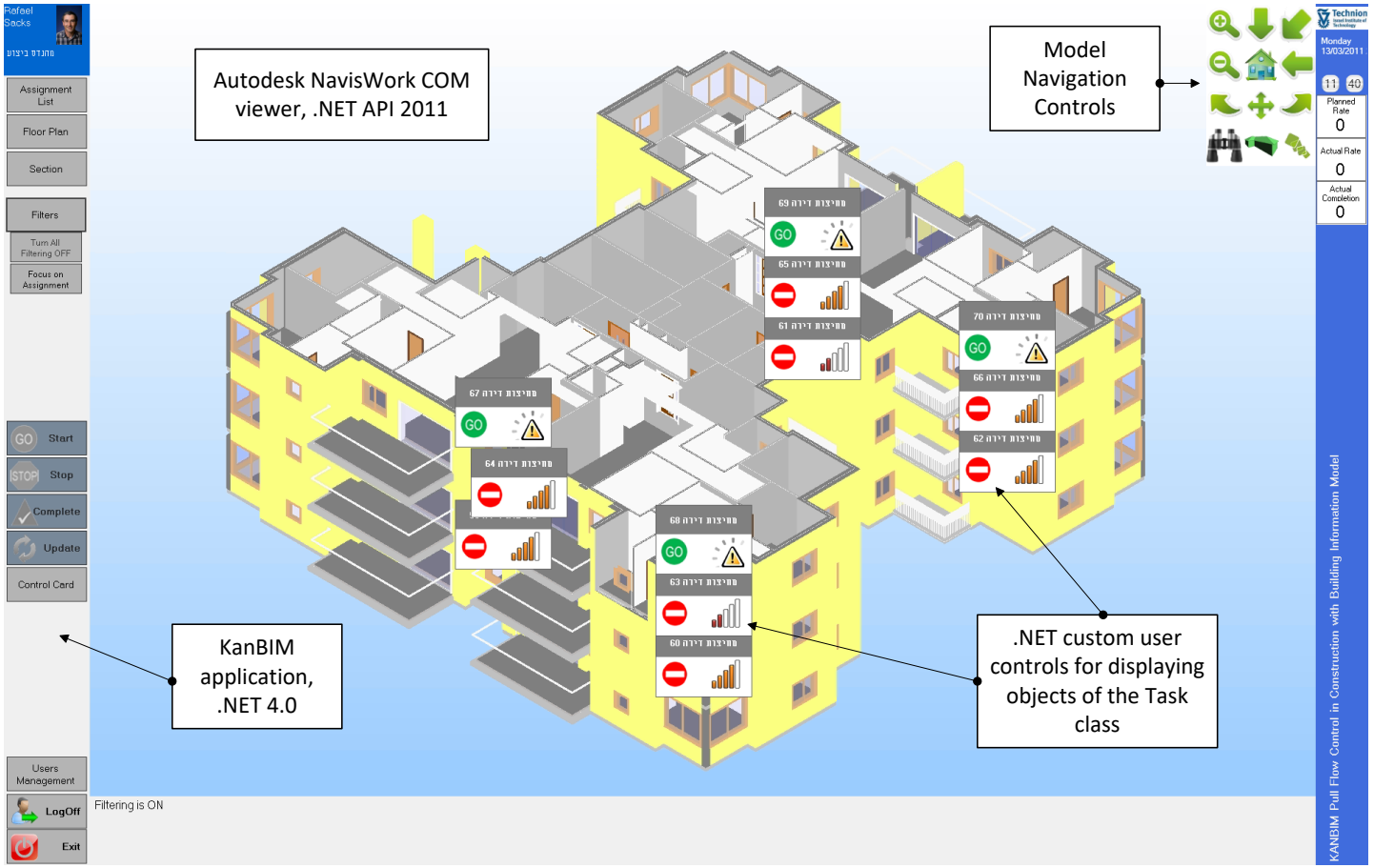
=

KanBIM

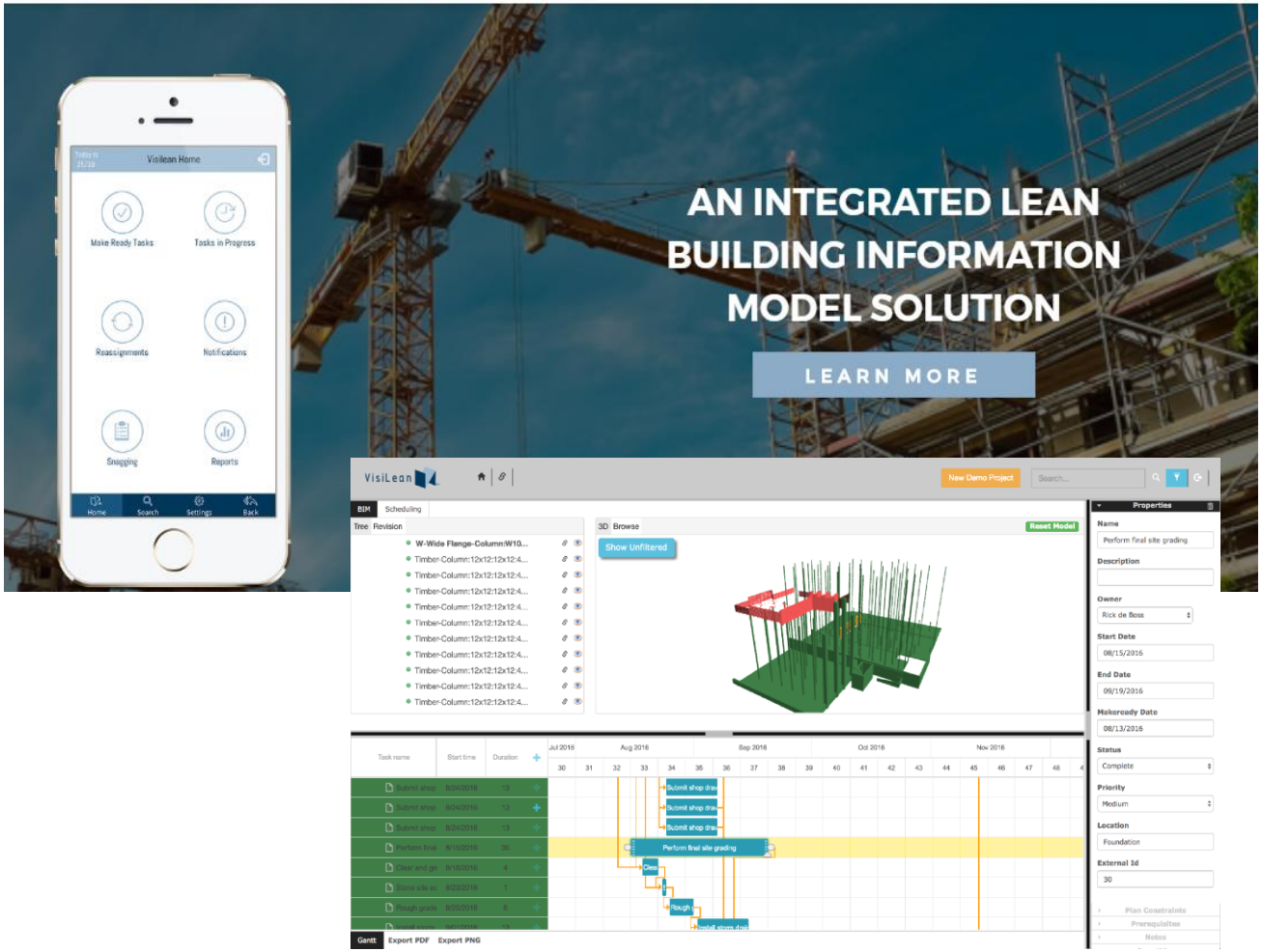
2009 KanBIM Mockup



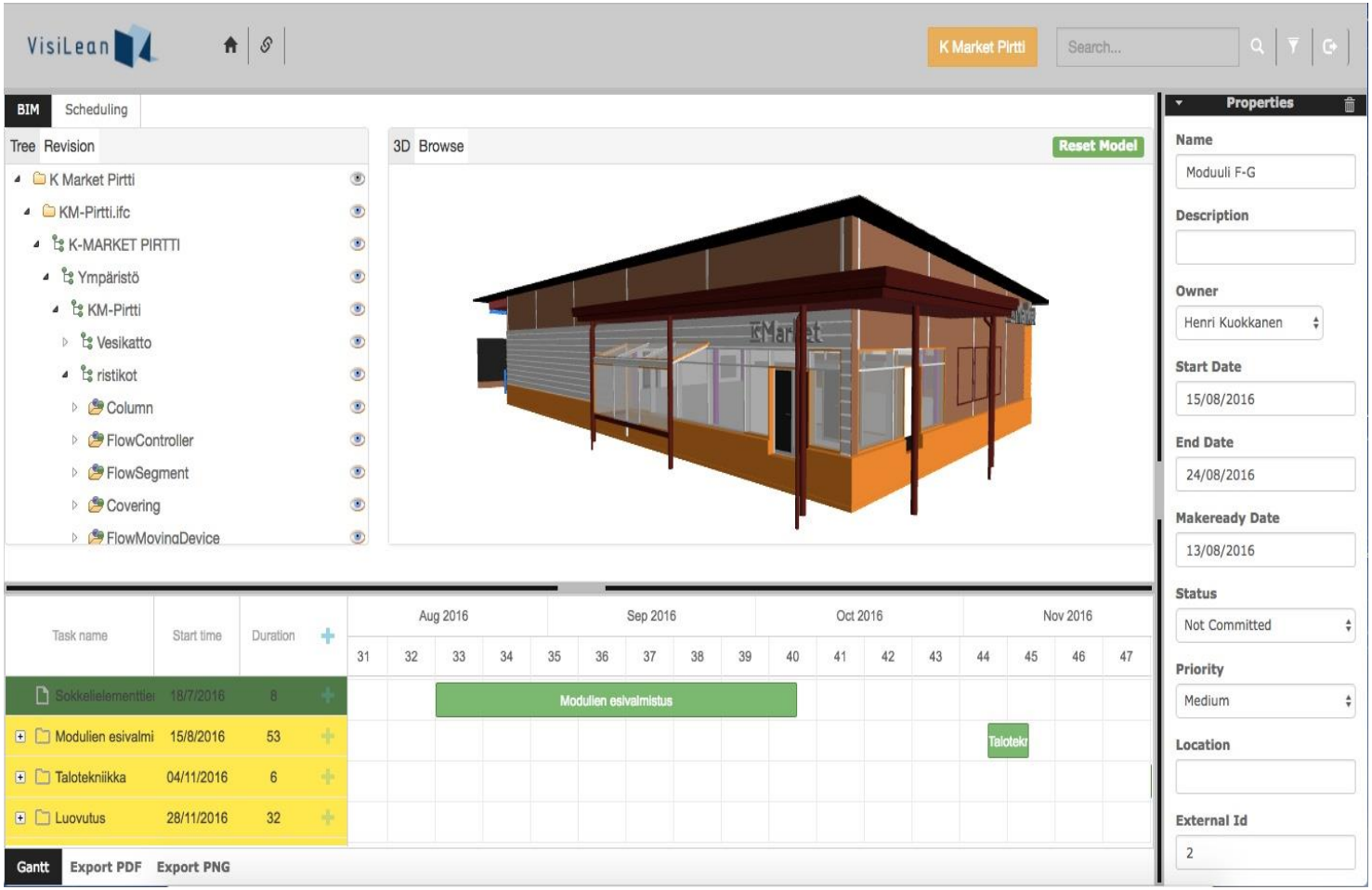
2011 KanBIM Prototype



2018 VisiLean



2018 VisiLean



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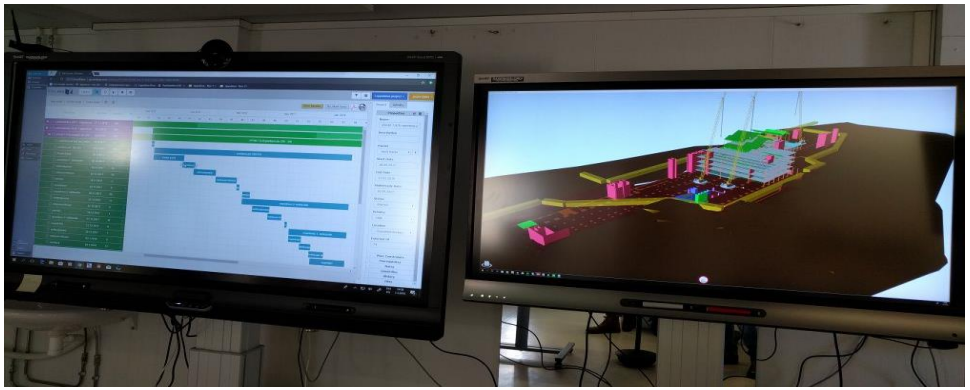
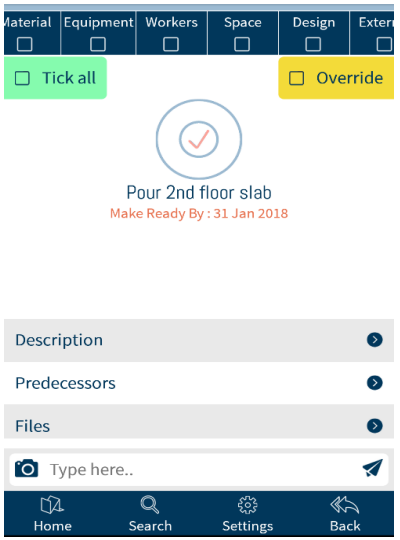
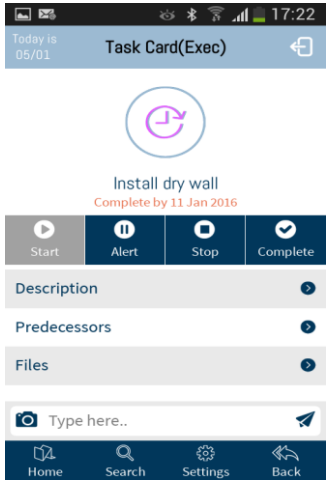
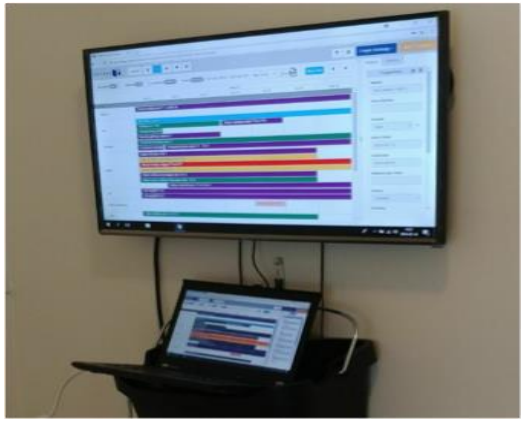


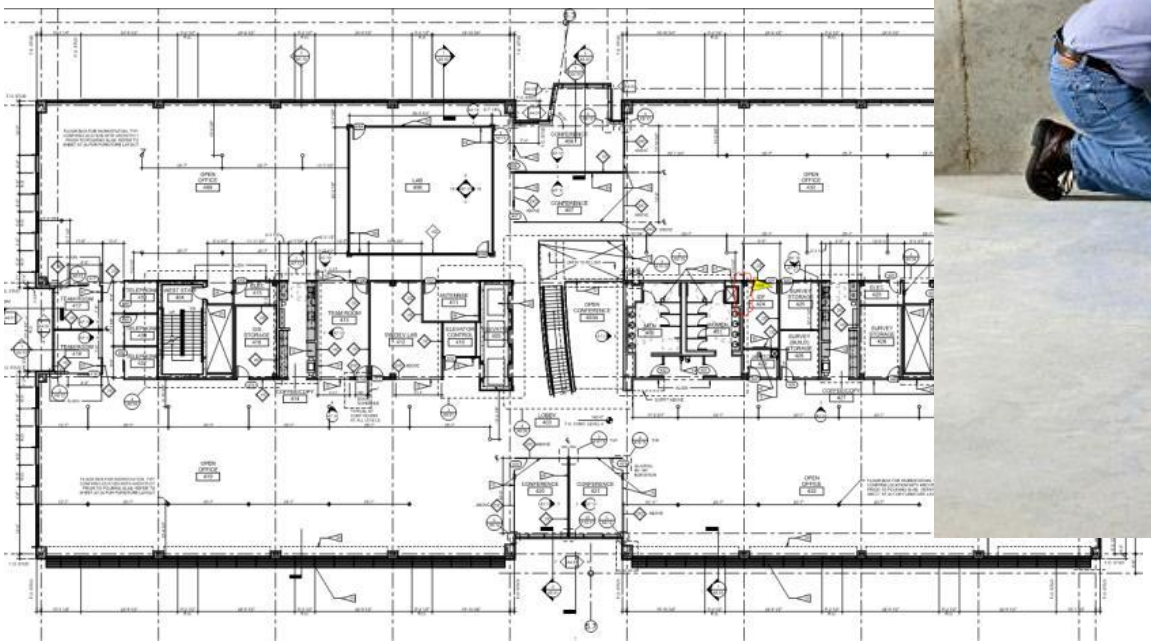






Layout of interior works in building construction

- Time Consuming
- Error-prone



Layout of interior works in building construction

State-of-the-art solutions, 2016

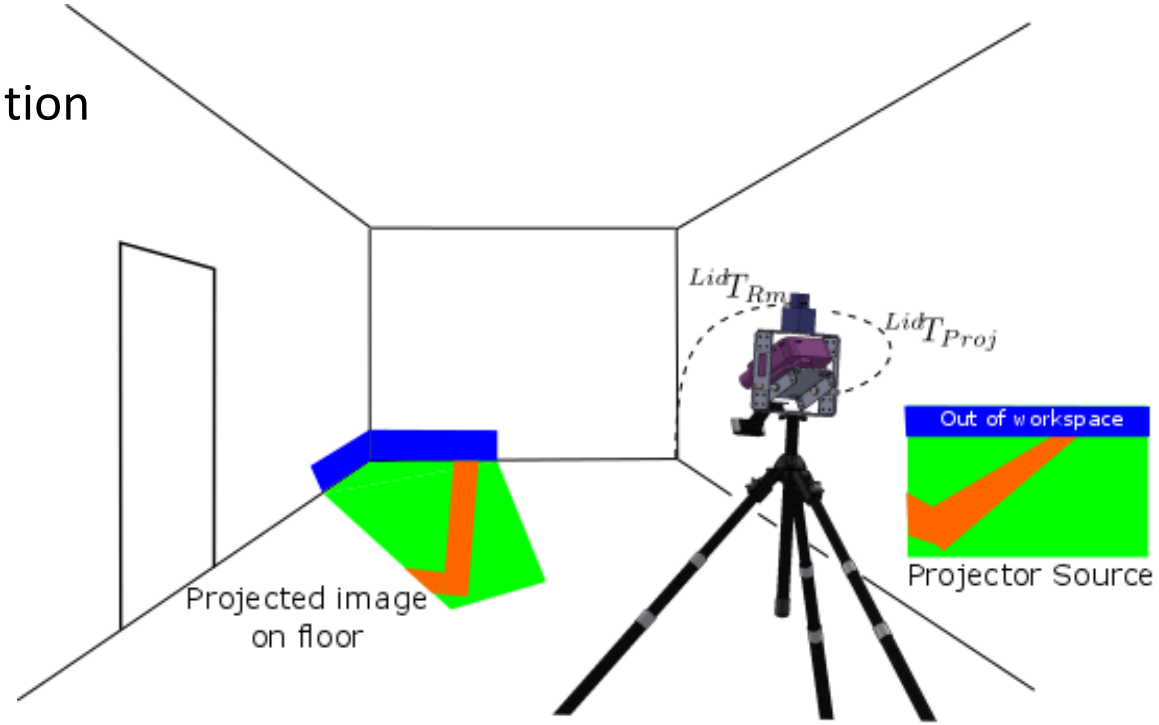
- Manual marking and layout
- Robotic Total station
- Augmented reality – Hololens, Daqri, etc.

Layout of interior works in building construction

2016 Research

Hands-free solution

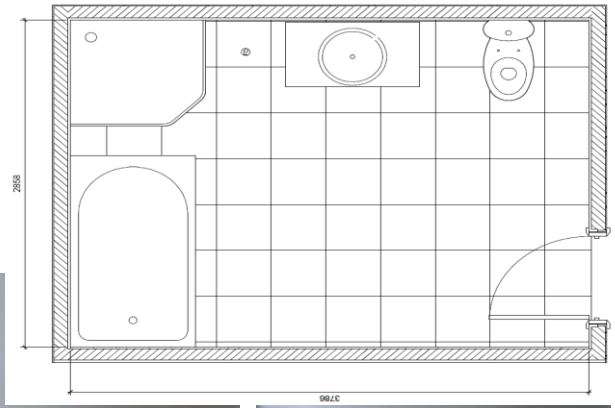
- Localization
- Calibration
- Projection



Degani, A., Li, W.B., Sacks, R. and **Ma, L.** (2019). 'An Automated System for Projection of Interior Construction Layouts' IEEE Transactions on Robotics and Automation, Vol. 15 No. 4, pp. 1825 - 1835.

Layout of interior works in building construction

2017 Lab experiments



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Layout of interior works in building construction

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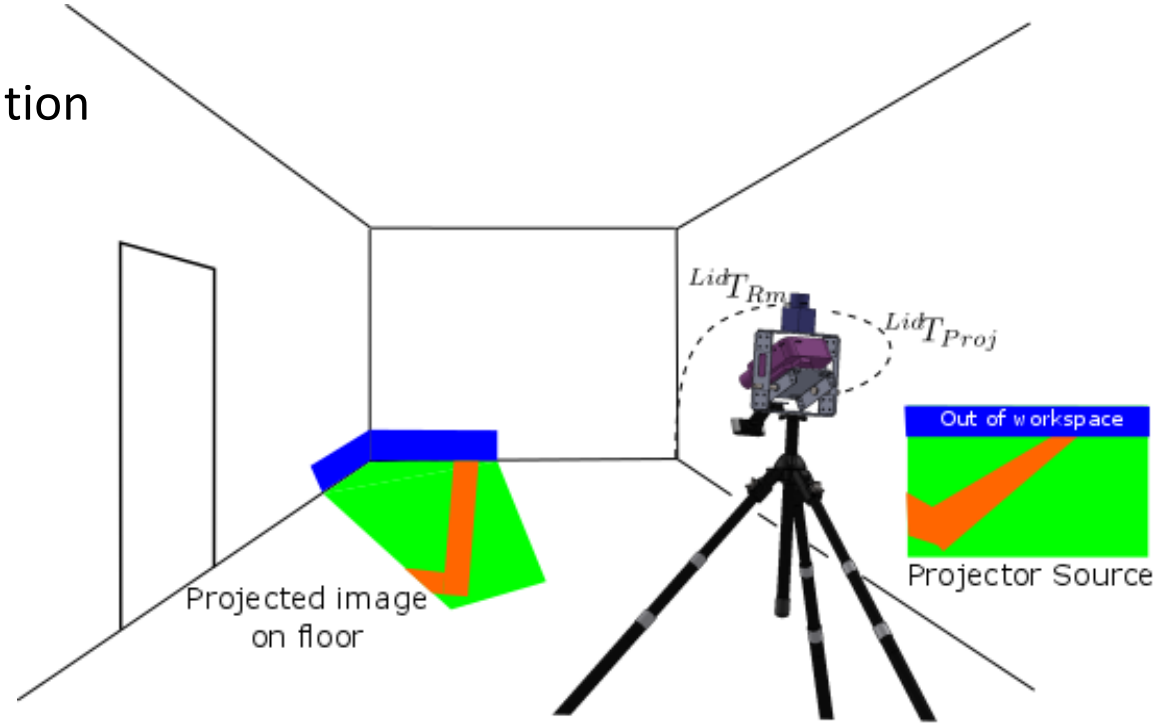

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Layout of interior works in building construction

2018 Startup Implementation

LIGHTYX

A device that accurately projects an augmented reality view of construction plans on the physical environment – in one click

Deliver work product and process information
Monitor construction quality
Report project progress status to stake-holders

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The House of Construction Tech

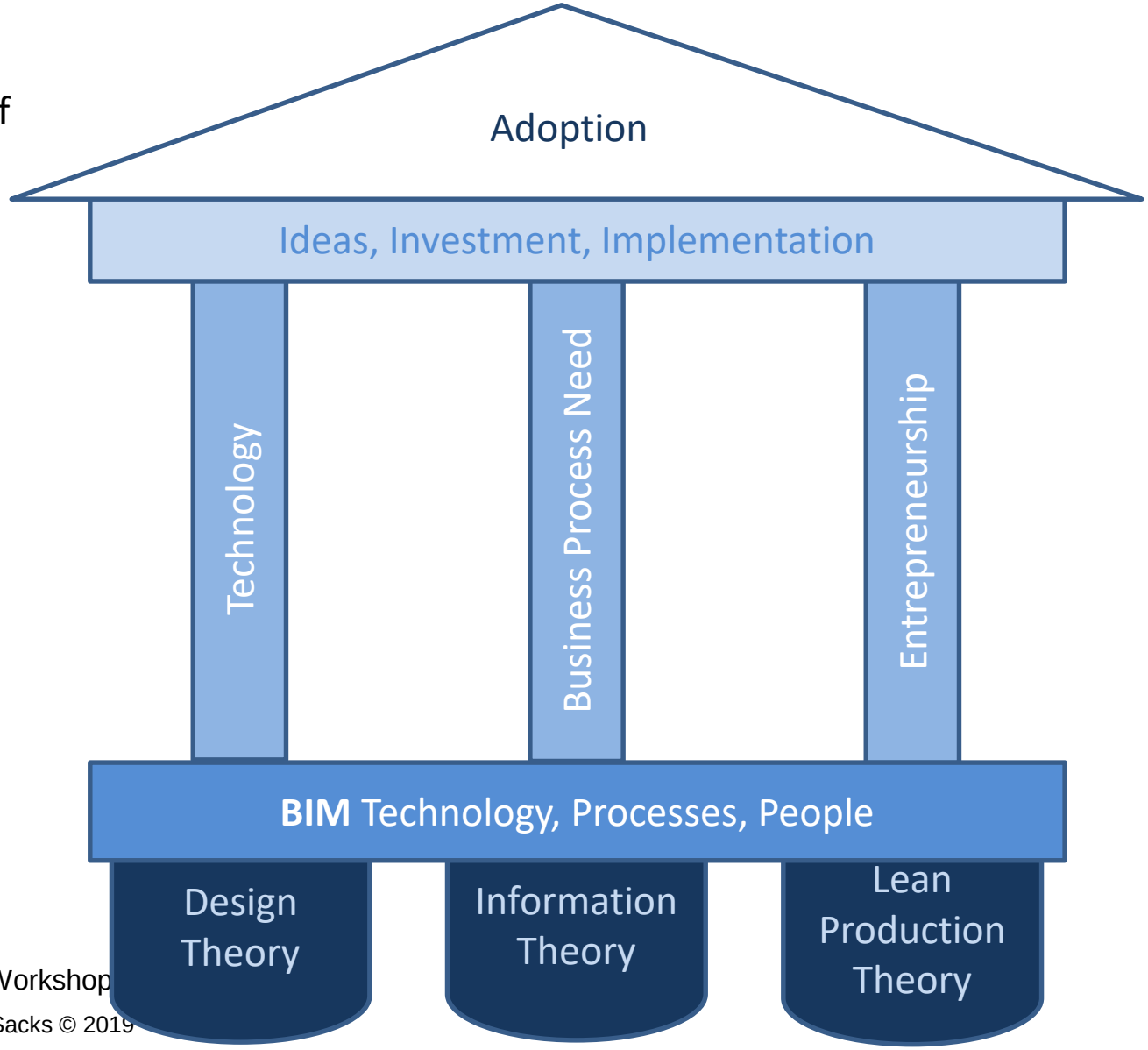
Adoption roof

Innovation beams

Construction Tech columns

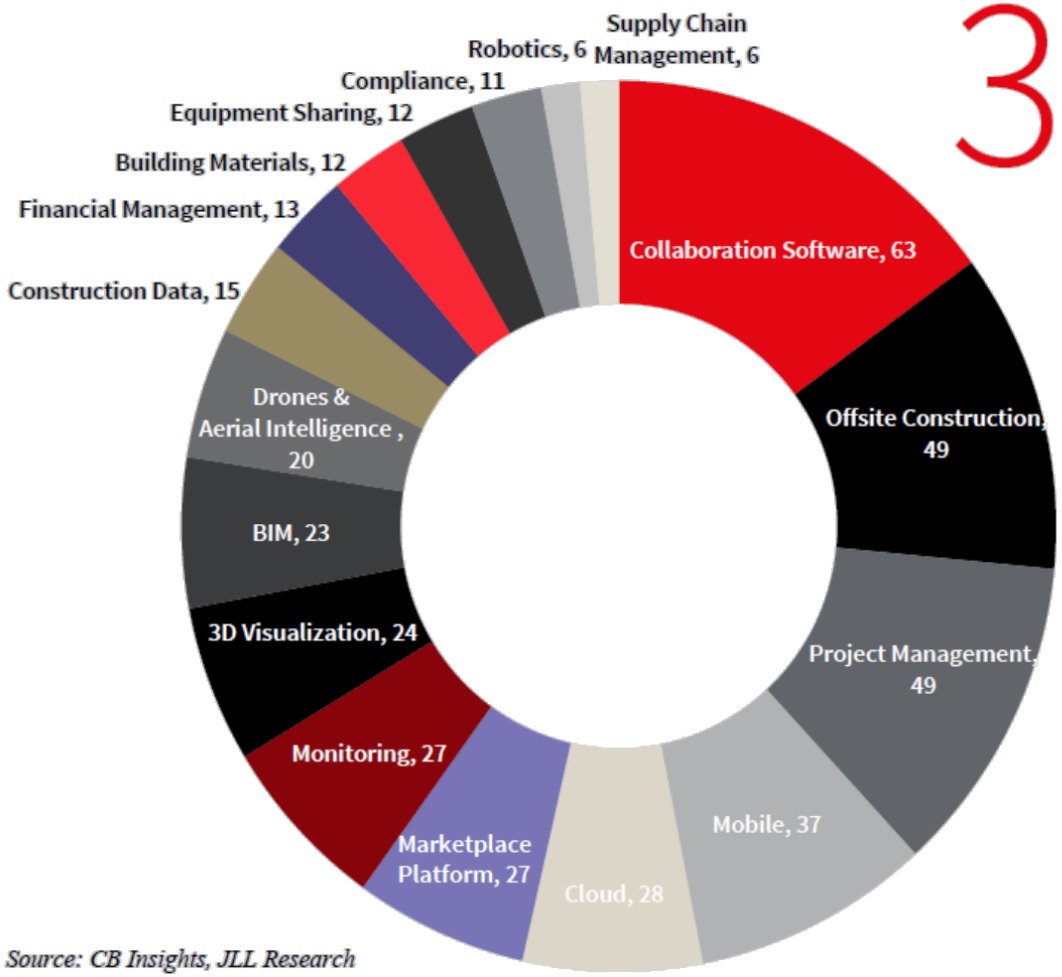
BIM foundation

Theory piles



Construction Tech Scope

Where Construction Technology startups are innovating
(by number of startups in category)



Source: CB Insights, JLL Research

3 Number of Unicorns in Construction Technology to date
(startups valued over $1B)

- Katerra
- Procore
- Uptake

Digital Twin Start-ups in AECO

Conclusion – key questions for debate

What are the possible pathways for adoption of Digital Twins technologies and practices in the Built Environment?

Propositions that may lead to answers…

- *Construction Tech has largely followed these paths to adoption:*

For example: 4 of the 5 major BIM authoring software; Revit, Tekla, ArchiCAD, Digital Project

- *The value of BIM is in the software and in the process. BIM processes are delivered through private architecture and engineering consultants, even to public clients. BIM companies sell software subscriptions.*

- *The value of Digital Twins for Infrastructure is in the information. DT vendors generate value by generating, organising and making information accessible.*

Summary: Tech transfer and market penetration

- **What industry business models are needed to best exploit Digital Twins?**

Three factors shape the business models:

1. The long-term source of value for digital twins accrues from savings in operations, maintenance and learning for new development of buildings and infrastructure. Scale of operations is necessary to leverage that value, and it requires long periods of time. Thus the business models must either address large clients only, or they must aggregate small scale owners and operators to create a critical mass of value. This suggests that the 'low hanging fruit' – i.e. **the main clients for digital twins of buildings and infrastructure – are large scale public or private owners and operators. A good business model will address these clients first.**
2. The value of digital twins for infrastructure is stored in the information. **Digital twin vendors can generate value by generating, organising and making information accessible,** rather than selling software, which would fast become a commodity.
3. **Digital twin models cannot be compiled by the staff of building or infrastructure owners**, for two reasons: a) highly specialized knowledge is needed for compiling digital twins, and b) the effort for compiling a digital twin is concentrated at the start of their life (whether from existing infrastructure or at the handover from a project built with BIM).

Summary: Tech transfer and market penetration

- **What industry business models are needed to best exploit Digital Twins?**

Thus digital twin business models must offer large clients two services:

a) a **digital twin compilation service**. This should be automated as far as possible, such as artificially intelligent acquisition of models from photogrammetry or laser scanning, collected over time.

b) a **digital twin information management (curation) service**. This should make the information easily accessible yet secure (access to the right people only), and amenable to artificially intelligent processing. Pre-prepared or configurable dashboards for analysis results are not enough – an API and a sound database design for developing customized simulations, analyses and interfaces are needed.

Summary: Tech transfer and market penetration

- **How should such models be introduced or promoted to achieve fast market penetration?**

Two modes appear to be likely and reasonable:

1. **Startup companies** offering some unique technology offering in terms of compilation and curation, together with a method to scale their service provision. These are two quite different aspects, but both are essential. They will require capital to survive long enough to achieve a critical mass of live/operating digital twins that generate revenue.
2. **Technology vendors that offer building or infrastructure operations software and hardware**, including monitoring and sensing equipment, with the scale needed to develop and implement a comprehensive digital twin solution and service.

Summary: Tech transfer and market penetration

- **What level of maturity should Digital Twin Tech achieve to be attractive to industry?**

To some degree, the answer is the reverse of the question – digital twin tech solutions from other industries are already well developed and sufficiently sophisticated to cope with building and infrastructure implementations. The more important question is "**What level of maturity should building and infrastructure owners and/or operators achieve in order for them to generate value from operation of their assets using digital twins?"**

Potential digital twin clients need a degree of sophistication and deep control over the operations of their assets in order to derive the potential value. This is not only about employing and/or training the right staff with the right skills to operate digital twin systems, it is about having the ability to make decisions and implement management systems based on rich information. **Given that large organisations are by nature difficult to change, particularly with regard to sophisticated technology implementation, this appears to be a bigger challenge than the maturity of digital twin technology.**

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