1. nLink concrete drilling robot
2. Shimizu welder robot
3. Construction Robotics SAM 100 semi-automated brick laying robot
4. Taisei Corporation and University of Tsukuba T-iROBO slab finisher
5. Drywall robot Build-R
6. Tsukuba University Hal exoskeleton
7. Tokio University of Science muscle suit
8. NEDO project teleoperation of construction machines
9. Built Robotics self-driving excavator

Motivation & Background
Research questions

• What type of robotic innovation is viable and under which conditions?
• What are the main robotic implementation challenges?
• Which dependent and independent variables will influence most the implementation?
• How many product, organization, and process boundaries need to be crossed to make a robot cost and schedule effective?
Case Study 1
Motivation & Background

Analysis method

Robotics research

Ghrayeb et al. (2004), Zarrouk et al. (2018): hardware & software design, path plan, cost per unit, output uniformity

Thrun et al. (2016): speed


Construction robotics research

Technology-focused

Bruzl et al. (2016): Path plan, quality, speed

Collision avoidance


General


Kangari & Halpin (1990), Skibniewski (1998): organization, Workforce impacts

Construction management research

Taylor & Levitt (2004): innovation diffusion challenges


Hartmann et al. (2007): 4D schedules

Slack et al. (1995), Thompson (1967): workflows and interdependency

Independent Variable

Dependent Variable
Methodology

**Quantitative data**
- Robot task reports
- BIM LOD and clashes

**Qualitative data**
- Interviews to nLink
- Interviews to GC
- Subs surveys
- Site pictures / videos

**Analyze if robot is viable**

**Independent variables:**
- Which task to automate?
- What robot to use if any?
- Where to deploy first, how?
- How wide to cast the organizational net?
- Which process to introduce the robot?

**Dependent variables:**
- Schedules (LBS, 4D)
- Cost
- Workflow
- Quality
- Safety
Analyze if robot is viable

- Schedules (LBS, 4D)
  - 1 hole (-33%), 1 zone (+8 day), 4 zones (-1w), optimized (perfect cycle time), 4D visualize and plan for the robot
- Cost
  - Robot sub, extra 3D hanger, added design time, -40 man hours: $29,000 / 6 (4 subs + GC + owner)
- Workflow
  - Coordination time, drill per sub or per diameter, automated info transfer
- Quality
  - Rework, QC w/visual management, site cleanness
- Safety
  - Overhead drilling from 74% to 1.3%, noise reduction
Systemic innovation:
Involves a set of companies to spend time and cost on mutual adjustment & coordination.

Project zones
Automated data acquisition and coordination: BIM

6 participants > 8 boundaries
Organization variance

Systemic innovation: Involves a set of companies to spend time and cost on mutual adjustment & coordination.
How general is this information and this approach to analyze other types of robots?
Case Study 2

Information:
Structures and architecture BIM updated until one day before

Robotic operation:
- Lift and fasten tool
- Battery power
- Machine vision identification (QR code at mm level)
- Intelligent navigation system (10cm tolerance)
- Robot operator and site cutting crew

Limitations:
- Installation of full boards (90cm x 250cm) only - cutting not integrated
- Installation of ceiling not possible yet
Case Study 3
Next Steps

Case Study 1: Drilling robot completed
Case Study 2: Drywall robot completed
Case Study 3: ... completed
Analysis and comparison of cases finished

Existing research of robotics in construction studied and analyzed
Existing manufacture evaluation frameworks studied

Robotics Evaluation Framework developed and validated

Motivation & Background  Case Study 1  Case Study 2 & Next Steps
Next Steps

Robotics Evaluation Framework
developed and validated