Smart Crane Solution for Safe Hoisting

Dr Meghdad Attarzadeh
NTU
Meghdad@ntu.edu.sg
23 October 2017
Outline

1. Problem Statement & Current Challenges
2. The Developed System
3. Project Innovations
4. Pilot Project
5. Productivity Improvement
6. Future Collaboration - Smart Hoisting for Heavy Precast
Current Practice: experiencing a major shift from the traditional methods of intensive manual labour towards the utilization of automation.
Objective

To enhance the **Workplace Safety and Health (WSH)** for construction site logistics management, Hoisting and Installation processes for the heavy lifting of Precast Elements.

- Manual process prone to human errors
- Human errors can be very costly
- “Blind Spots” in tower crane hoisting
- Low Productivity for Hoisting Process
- Miscommunication can be very dangerous
- No reference to BIM design platform
The Developed System

A safe, reliable, intelligent and semi-automated logistics and crane navigation system:

1) Integrated Digital Delivery (IDD);
2) Network of internet of things (IoT);
3) Signal parameters (Digital IDs) are collected through the various smart sensors (RFID systems-Material Tracking);
4) Wireless smart sensors network along with smart camera technologies help for tracking and monitoring of operations;
5) Computerised simulation system for sequencing activities to avoid activities clashes, can be used for JIT delivery;
6) Able to auto-detect and semi auto-position the precast element closer to its coordinate with micro-adjustment to be done by operator (Smart Hoisting/Installation);
7) Information are displayed in the LCD Touch screen to guide the crane operator.
“Implementation of a Smart and Semi-Automated Precast Elements Logistics Management and Installation System”

**Objective**
Enhancing the Productivity, Efficiency and Safety of the Precast Elements Logistics Management, Hoisting and Installation process of housing projects through BIM based semi-automated System integrated with Positioning and sensor technologies.

**Deliverables**
- Development of **applications and add-ons** to support functions in the proposed process for the smart crane system, such as scheduling, coordination, sequencing, on-site inventory checks and assembly.
- Development of **good practice guidelines** for the proposed system.
- Host of **site visit(s)** for industry when notified by BCA.
- Share experiences gained from the PIP with the industry.
- Submission of a **case study report** on the use and operation of system.

**Funding Agency:** BCA (PIP Scheme)
**R&D, Co-Applicant:** NTU – CoE for BIM
**Industry Partner, Main Contractor, Applicant:** Kimly
**Support by:** SLA for SiReNT
**Technology Partners:** Trimble SEA (BIM), Geoscience Consulting (GPS) and Intrasys (RFID) Vendors

**Project development period:** Dec. 2015-Oct 2017

**Pilot Project:** Executive Condominium Housing Development Comprising 11 Blocks Of 12 Storey Residential Buildings (525 Units) located at Yishun Street 51 (Y51EC). We have focused on Blocks 7&8 for implementation of the proposed system.
Main Characteristics and Benefits of The Developed System

1) Provide a **holistic** precast components logistics management, inventory checking and tracking, hoisting and installation system.

2) Generate digital identification code for precast components, able to **integrate** the *Logistic Management* and *SMART crane system* with BIM.

3) The system **updates** database and **Building Information Model automatically**.

4) The system supports worksite for **JIT delivery** and stock/inventory control. It provides information of the progress at construction site which helps to meet JIT delivery (*BIM-based* construction site JIT inventory checking and tracking system).

5) SMART crane semi-auto system pre-determine the actual installation coordinates of the component based on the Building Information Model.

6) SMART crane semi-auto system helps to **semi-automatically** detect, hoist and locate the precast component at the final setting location.

7) **Crane Operator still control the crane**, do micro-adjustment to lower the component into final position.
Components structure of the Developed System

*Information flow for the developed system*

(1) Logistic Management

RFID System

Data collection during the delivery to site, storage, erection and installation

(2) Installation System
Functionality of the Developed System

SMART Crane System
BIM-based semi-automated System integrated with Positioning and sensor technologies

Includes two parts:
2. Semi Auto-position and tracking to assist the crane operator precast elements to identified locations.
Implementation of a Smart and Semi-Automated Precast Elements Logistics Management and Installation System

System structure and functionality of the Developed BIM-based semi-automated System Integrated with Positioning and sensor technologies
# Implementation of a Smart and Semi-Automated Precast Elements Logistics Management and Installation System

**BIM to Database, Precast BIM system integrated with database, real time position and logistics tracking**

![BIM to Database](image)

<table>
<thead>
<tr>
<th>SN</th>
<th>Panel Marking</th>
<th>Tag ID</th>
<th>GUID</th>
<th>Name</th>
<th>Dimensions</th>
<th>Weight</th>
<th>location in BIM</th>
<th>Real time location</th>
<th>Error (RMSE)</th>
<th>Is Error accepted?</th>
<th>Yes/No (0/1)</th>
<th>Date</th>
<th>History of status</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>length</td>
<td>width</td>
<td>height</td>
<td>(X, Y, Z) coordinates</td>
<td>Level, x and y axes</td>
<td>(X, Y, Z) coordinates</td>
<td>Error threshold</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Erected and Installed</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Erecting and Installing</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Stored at Storage Area</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Stored at Storage Area</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Delivered to the Site</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Fabricated at Production Source 1</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Fabricated at Production Source 2</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>In production</td>
</tr>
<tr>
<td>9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>In production</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>In production</td>
</tr>
</tbody>
</table>
Implementation of a Smart and Semi-Automated Precast Elements Logistics Management and Installation System

RFID handheld readers

RFID System at site

RFID tags
RTK-GNSS system mounted at crane hook block

1. RTK-GNSS system
Implementation of a Smart and Semi-Automated Precast Elements Logistics Management and Installation System

Smart Camera system mounted at crane hook block
Implementation of a Smart and Semi-Automated Precast Elements Logistics Management and Installation System

Smart camera day and night views
Implementation of a Smart and Semi-Automated Precast Elements Logistics Management and Installation System

LCD touch screen monitor located at crane cabin

Centralized Computer System located at site office

System in the Centralized Computer System located at site office and the LCD touch screen monitor located at crane cabin
Implementation of a Smart and Semi-Automated Precast Elements Logistics Management and Installation System

LCD touch screen monitor located at crane cabin
Media Coverage of the **Smart Crane System 0.5** in Straits Times, 4 Dec 2016

http://www.straitstimes.com/singapore/smart-crane-for-precast-building

**Modification of the Tower Crane (TC6) for Blks 7 &8 of the SIGNATURE AT YISHUN, the Executive Condominium project constructed by Kimly Construction**
Implementation of a Smart and Semi-Automated Precast Elements Logistics Management and Installation System

Real-time Path Monitoring of precast element hoisting operation

Video capture of smart crane system in tower crane cabin during hoisting of precast panel: B7L11-7-PWAL10007
Implementation of a Smart and Semi-Automated Precast Elements Logistics Management and Installation System

Safety Record for the Hoisting Process

Video record of the hoisting process as captured by camera on the crane hook block of smart crane system 0.5 during hoisting of precast panel: B7L10-7-PW5014
Implementation of a Smart and Semi-Automated Precast Elements Logistics Management and Installation System

Project Innovations

The main innovations of project/Developed System are listed below.

1. Smart and semi-automated real-time Logistics management and inventory tracking; RFID system integrated with BIM system and database to track the storage area on site (through scanning the precast elements’ tag IDs and slot IDs by manpower) and automatically real-time update BIM and database.

2. The proposed safe lifting/hoisting path for each precast element is based on the 6-Key points method developed in this project, it is generated and shown in BIM environment instantly to guide the crane operator for safe hoisting of precast element. An algorithm (computer programming) was developed for the proposed method based on the site practice and safety considerations.

3. RTK-GNSS tracking system with real time correction integrated with BIM system and database was developed to visualize the precast element in BIM environment while it is hoisting and installing and automatically real-time update BIM and database, i.e. visualization the actual path of the hoisting and installation of the precast element in BIM environment; positioning accuracy, real-time pre-designed hoisting path to guide the crane operator to hoist precast elements safely and install them to positions accurately with desirable precision (less than 20 cm).

4. Installation of wireless video camera system on the crane hook block provides the crane operator inside the tower crane cabin with real-time visibility of the hoisting process including the hosting locations, flight paths, and final installation at high floor, this removes the blind spot that tower crane operator is now facing.
Future possibilities

1. The crane operator need not be in the cabin in future to operate the crane; the crane can be **remotely operated** by using the proposed system at an **e-kiosk** located at the construction level (Ground communication with crane system).

2. With reference to **PM comment** that how **PSA** has improved their crane operation with the help of technology, whereby **one crane operator can now operate a few cranes**. This could be possibility in future at construction sites.

---

**Architectures of the proposed System**

Remote control Mechanism for Smart Crane System
PILOT PROJECT

OWNER: JBE HOLDINGS PTE LTD

ARCHITECT: DESIGN LINK ARCHITECTS PTE LTD

C&S ENGINEER: KCL CONSULTANTS PTE LTD

M&E ENGINEER: RANKINE & HILL (SINGAPORE) PTE LTD

EXECUTIVE CONDOMINIUM PROJECT CONSISTING OF 11 TOWER BLOCKS WITH 12 STOREYS RESIDENTIAL FLATS AND 1 BASEMENT CARPARK
PROJECT LOCATION

Site location
Total no. of Precast elements for Blks 7\&8: 65+ 65 = 130 pcs / floor
PRECAST CONSTRUCTION

Type E1

Type E1

Lift Core

Type D1

Type C1

Type C3

BLK 7

BLK 8
SITE UTILISATION PLAN

TC 6 for Research Area
1

The system has resulted in **manpower saving** (Manpower and Man-hours reduction) at each innovation area, i.e. logistics, inventory checking and hoisting and installation.

2

The developed system helps the tower crane operator for “**heavy**” and “**blind**” lifting.

3

The proposed system transforms the existing process to a **systematic** way of precast construction, **Automation in Construction**.
<table>
<thead>
<tr>
<th>#</th>
<th>Action in present process</th>
<th>Activities</th>
<th>Action in proposed process</th>
<th>Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hard Marking as Label, Manual tracking of elements’ production, Based on 2D drawings</td>
<td>Scheduling and Coordination (Sequencing of Precasting and Precast Elements logistic Management)</td>
<td>Using Sensor for precast elements tracking (ID), system propose sequence no., based on BIM</td>
<td>Saving of 2 manpower, Appx 10-20 % Man-hours saving</td>
</tr>
<tr>
<td>2</td>
<td>Hard Marking as Label, Manual tracking of elements’ storage location, Based on Hard Copy Print Outs (2D)</td>
<td>Inventory Check (On site) of Precast Elements</td>
<td>Using Sensor for precast elements identification (ID), real-time integration with BIM</td>
<td>Saving of 1 manpower, Appx 30 % Man-hours saving</td>
</tr>
<tr>
<td>3</td>
<td>Manually Operation, 2D based, rely on manpower decisions (signal man, etc.)</td>
<td>Hoisting and Installation of Precast Elements</td>
<td>Sensor, smart camera system, and Positioning System-based system real-time integration with BIM</td>
<td>Safe hoisting due to added visibility provided by camera and developed system, reducing number of “blind lifts”</td>
</tr>
</tbody>
</table>
Future Collaboration - Smart Hoisting for Heavy Precast

Increase the awareness of crane operator through BIM/VDC-based hoisting path planning integrated with smart video cameras system, sensors and positioning technologies.
Thank You

Q&A

Dr Meghdad Attarzadeh
Meghdad@ntu.edu.sg