

# INDOOR TRACKING OF CONSTRUCTION WORKERS USING BLE: MOBILE BEACONS AND FIXED GATEWAYS VS. FIXED BEACONS AND MOBILE GATEWAYS

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# Introduction

- **Situational awareness** (real-time location of labor, material and equipment, and work status) is essential information for site managers
- The full potential of Lean construction tools and methods remains unrealized due to limited situational awareness
- This paper presents the work of two research teams using BLE technology to monitor resource location
- We examined two methods of deployment of BLE beacons and gateways:
  1. MB - mobile beacons and fixed gateways (MB)
  2. FB - fixed beacons and mobile gateways (FB)
- Field experiments were conducted in Finland, Israel, Peru, the Netherlands and China.

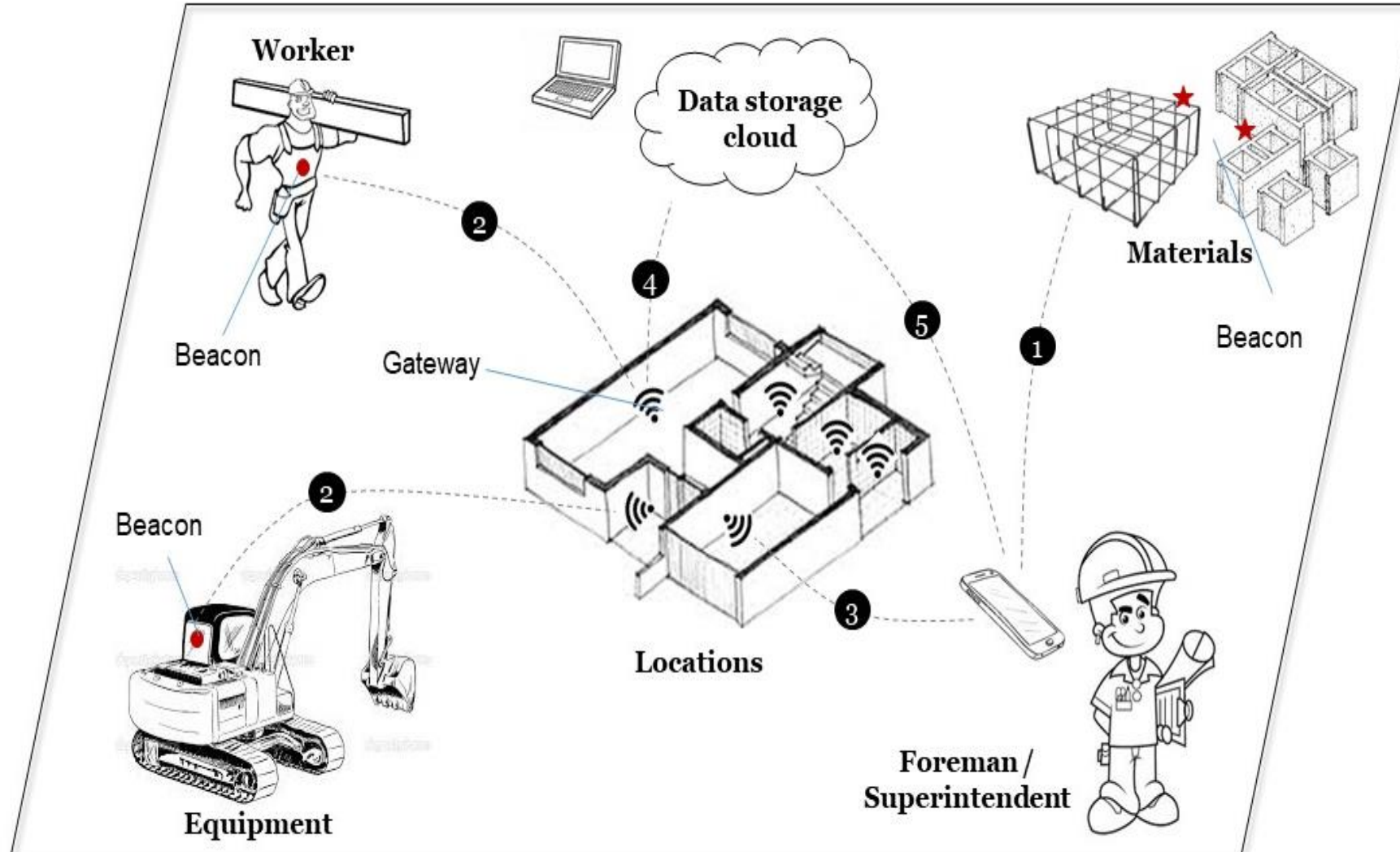
# Literature review

- The construction industry needs innovative management processes and software that exploit automated information collection and intelligent data processing (Sacks et al. 2010, Nath et al., 2015).
- Production control methods in construction traditionally rely heavily on social processes and manual input (Pradhananga, 2013)
- An intelligent real-time platform where all resources can be tracked and analyzed to support labor management (Lin et al., 2013), and automate the data recording process (Costin et al., 2012), is needed.
- For indoor positioning, of all the technologies, Bluetooth Low Energy (BLE) has proved to be cost-effective because of its high degree of implementation simplicity with minimal infrastructure and ease of calibration (Park et al, 2016)

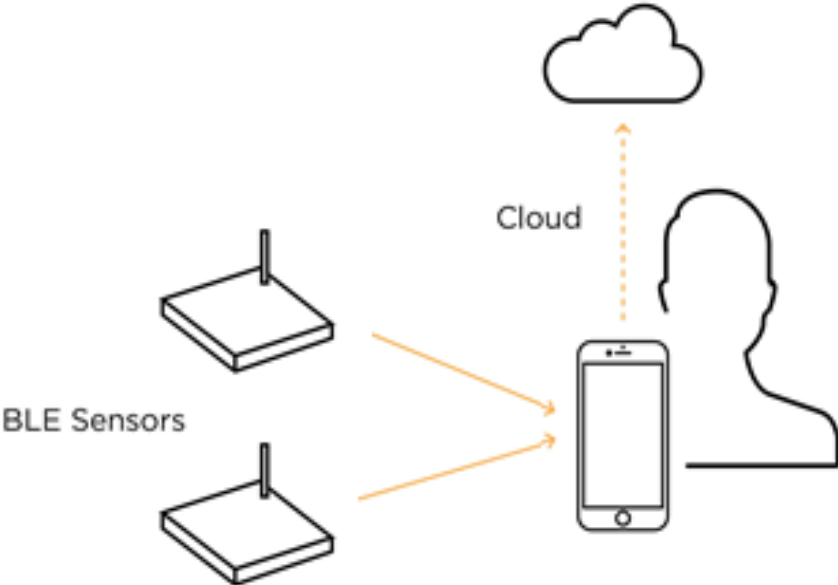
# Research questions:

- Do the MB or FB methods enable effective and efficient tracking the locations of resources, such as labour, material and equipment?
- What are the advantages and disadvantages of each of the methods?

# MB - Mobile beacons and fixed gateways



# FB - Fixed beacons and mobile gateways



# Project-level presence analysis based on MB tracking solution\*

## Case study/ Companies:

1. Residential building: Plumbing renovation (3 318 sqm)

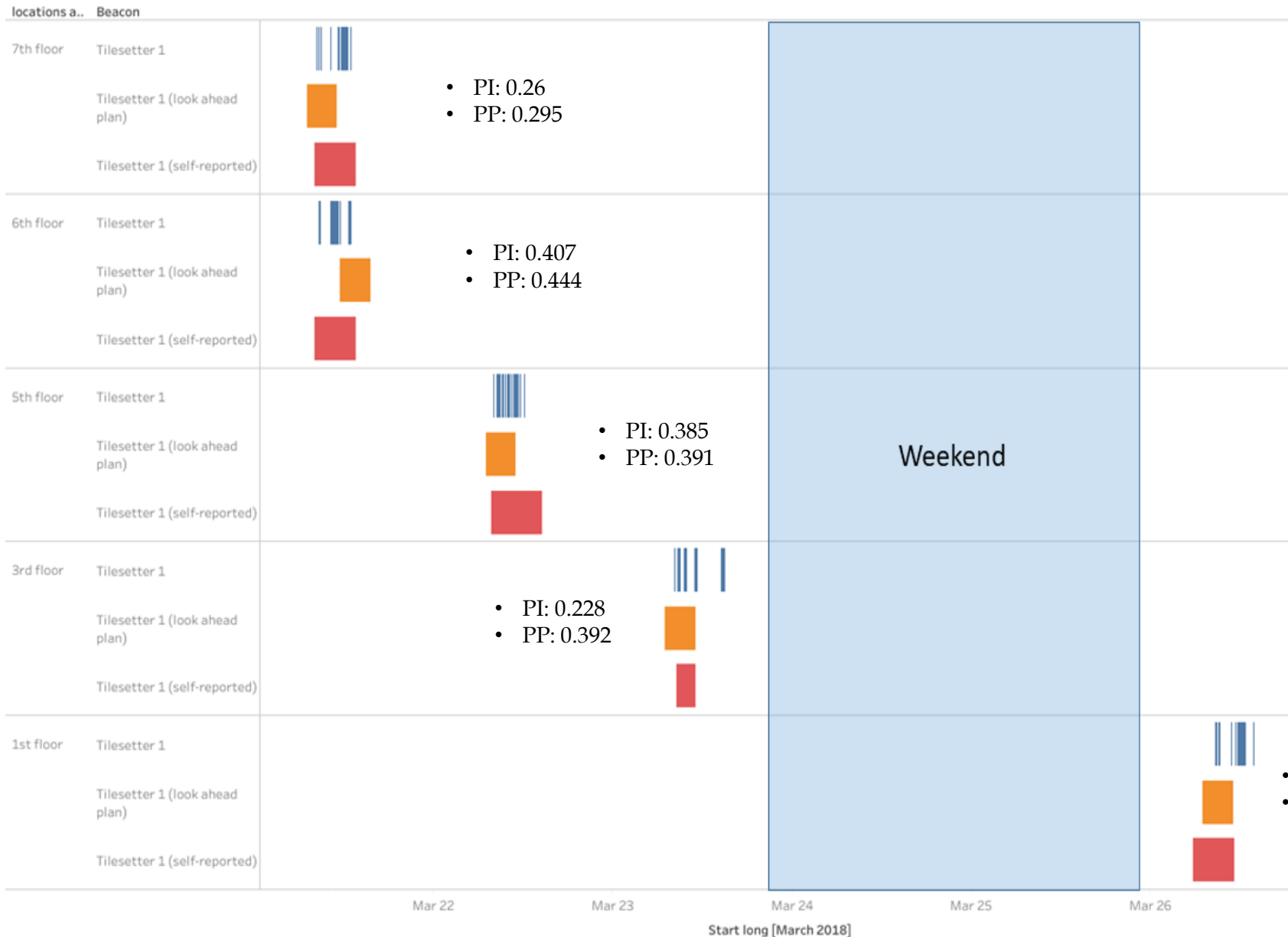
2. Office building (22 400 sqm)

3. Residential building (3869 sqm)

Case study	Number of tracking devices	Main objective
1	15 beacons on workers; 23 gateways in one jobsite	Worker tracking on apartment level
2	13 beacons on workers; 21 gateways in one jobsite	Worker tracking in open spaces
3	11 beacons on workers; 10 gateways in one jobsite	Worker tracking at the stairwell and floor levels

# Task-level presence analysis based on MB tracking solution

## Water insulation



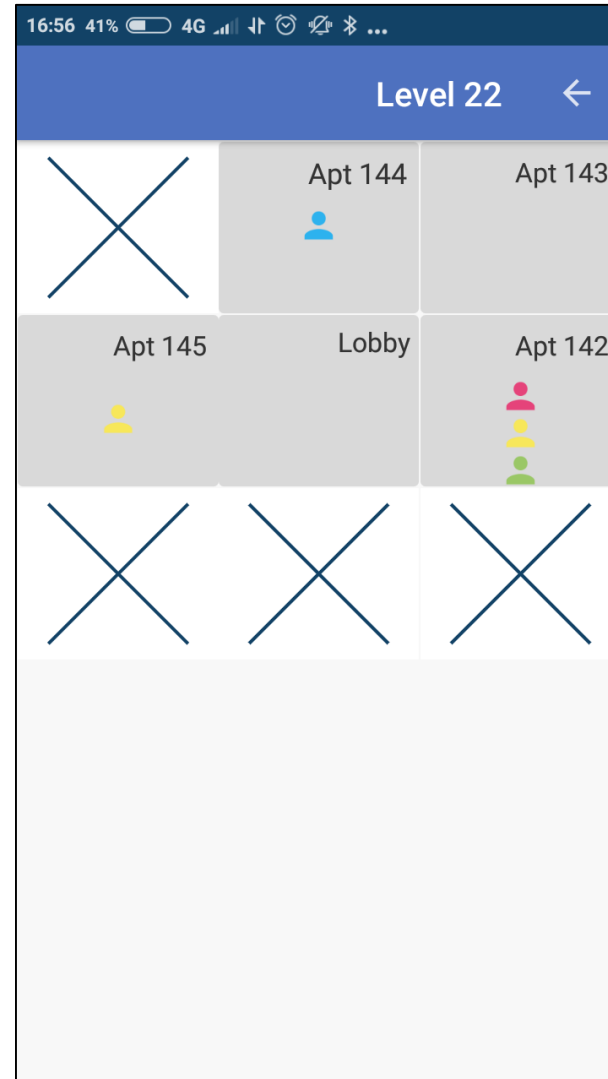
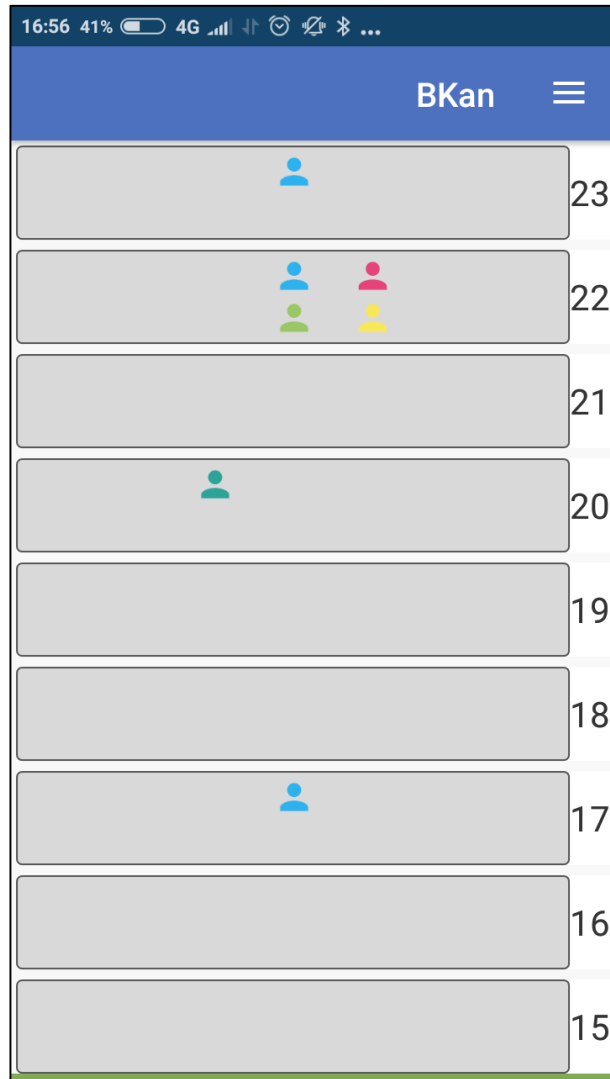
- Beacon
- Tilesetter 1
  - Tilesetter 1 (look ahead plan)
  - Tilesetter 1 (self-reported)

- PI: presence accumulated time divided by total detected time length of the task;
- PP: presence accumulated time divided by planned time length of the task;
- Average PI of the task: 0.32;
- Average PP: 0.39;





# Visualization of workers location using a smartphone application



# Comparison of the two solutions

## Example Project:

- 16 Floors residential building
- 1 Entrance floor
- 15 Tracked workers
- 20 Equipment piece
- 30 Material containers

	Fixed beacons - mobile gateways prototype (FB)	Mobile beacons - fixed gateways prototype (MB)
Hardware requirements- labor tracking	65 Beacons	23 Gateways 15 Beacons
Hardware requirements- equipment/ material tracking	50 Beacons	50 Beacons
<b>Total cost</b>	<b>460 €</b>	<b>1,675 €</b>

# Comparison of the two solutions

	Fixed beacons - mobile gateways prototype (FB)	Mobile beacons - fixed gateways prototype (MB)
<b>Setup &amp; Maintenance</b>	<ul style="list-style-type: none"><li>+ Short setup time</li><li>+ Minimal maintenance</li><li>- Application required for the installation</li></ul>	<ul style="list-style-type: none"><li>+ Short setup time</li><li>+ Minimal maintenance</li><li>+ Easy set-up, no mobile application required</li><li>- Gateways exposed onsite</li></ul>
<b>Cost</b>	<ul style="list-style-type: none"><li>+ Low hardware costs</li></ul>	<ul style="list-style-type: none"><li>- Higher hardware costs</li></ul>
<b>Feasibility in construction sites</b>	<ul style="list-style-type: none"><li>+ Minimum physical requirements</li><li>- High friction with workers</li></ul>	<ul style="list-style-type: none"><li>- Requires access to power</li></ul>

# Comparison of the two solutions

	Fixed beacons - mobile gateways prototype (FB)	Mobile beacons - fixed gateways prototype (MB)
<b>Accuracy &amp; Coverage</b>	<ul style="list-style-type: none"><li>+ Unlimited coverage</li><li>+ High accuracy in closed areas</li></ul>	<ul style="list-style-type: none"><li>+ Coverage and accuracy can be improved</li><li>- Temporary power requirements</li><li>- Internet required for gateways</li></ul>
<b>Reliability</b>	<ul style="list-style-type: none"><li>+ 98% accuracy in apartment scale positioning</li></ul>	<ul style="list-style-type: none"><li>+ Accuracy is high with detection in real time</li><li>- Signal coverage depends on gateway placement</li></ul>
<b>Data transmission rate</b>	<ul style="list-style-type: none"><li>- Every 5 minutes</li></ul>	<ul style="list-style-type: none"><li>+ Continuous</li></ul>

# Use case comparison

	<b>Fixed beacons - mobile gateways prototype (FB)</b>	<b>Mobile beacons - fixed gateways prototype (MB)</b>
<b>Labor monitoring</b>	<ul style="list-style-type: none"><li>+ High accuracy monitoring</li><li>- Requires smartphone compatibility and application installation</li><li>+ Workers consistently carry smartphones</li></ul>	<ul style="list-style-type: none"><li>+ Workers need carry only beacons.</li><li>- Workers might leave beacons on site</li><li>- Limited tracking precision due to lack of coordinates of floor plan</li></ul>
<b>Material &amp; Equipment monitoring</b>	<ul style="list-style-type: none"><li>+ Beacons can be used as material and equipment tags, straightforward can be reused</li></ul>	
<b>Movement data analysis</b>	<ul style="list-style-type: none"><li>+ A movement tendency index can reflect the workers' efficiency</li><li>+ Gaps in data flow can lead to gaps in information accuracy</li></ul>	<ul style="list-style-type: none"><li>+ Time-location analysis indicates the uninterrupted presence level at work locations</li><li>+ Task-level presence analysis compare schedules</li></ul>

# Conclusions

- Both methods are feasible for resource location monitoring in construction sites
- Both methods appear to provide sufficiently accurate and complete data for deducing
- The location data can support construction managers as an aid to improve their decision making
- Both methods provide data that can be processed to yield insights about workers' movement patterns and the construction waste

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Thank you very much!