



Applying heat maps to define workspace in construction based on real-time tracking system with coordinate positioning information

IGLC conference paper presentation

Jianyu Zhao, Olli Seppänen and Antti Peltokorpi

Aalto University, Finland



Jianyu Zhao



IGLC 28

BERKELEY, CA 6-12 JULY 2020

28th ANNUAL CONFERENCE OF THE
INTERNATIONAL GROUP FOR LEAN CONSTRUCTION

- Master of Science from Royal Institute of Technology (KTH), Sweden 2014-2016
Major in Real Estate and Construction Management
- Currently in 4th year of PhD studies at Aalto University, Finland
Research topic: Using real-time tracking system to improve production control in construction
- PhD supervisors: Prof. Olli Seppänen and Antti Peltokorpi

Introduction



IGLC 28

BERKELEY, CA 6-12 JULY 2020

28th ANNUAL CONFERENCE OF THE
INTERNATIONAL GROUP FOR LEAN CONSTRUCTION

- Construction sites are often in chaotic environment which leads to massive efficiency loss and waste due to managerial reason and resource mishandling (Akhavian et al. 2016).
- Workspace is a key resource in construction sites that are required by construction activities (Akinici et al. 2002).
Alongside workspace management in construction, several lean methods such as Location-Based Management System (LBMS) and Takt Time Planning (TTP) are also applied to eliminate waste and enhance productivity at work locations onsite.
- Real-time tracking solutions and heat-map applications in construction from previous studies.

Research questions



IGLC 28

BERKELEY, CA 6-12 JULY 2020

28th ANNUAL CONFERENCE OF THE
INTERNATIONAL GROUP FOR LEAN CONSTRUCTION

- This paper aims to develop automated process of workspace detection based on coordinates of workers and explore various uses of workspace heat maps to serve the purposes of lean construction principles. We applied the same tracking system as Badihi et al. (2019) but extend the method to generate the heat maps of workers' onsite presence.
- How can a coordinate-based real-time tracking system be applied to real-size construction projects?
- How can heat maps of workers' presence onsite be used to serve lean approaches in construction such as takt time planning and uninterrupted presence detection?



IGLC 28

BERKELEY, CA 6-12 JULY 2020

28th ANNUAL CONFERENCE OF THE
INTERNATIONAL GROUP FOR LEAN CONSTRUCTION

Method

Case selection

A single-case study approach was chosen as a research method. The location of the case was in a Chinese city close to the capital Beijing.





IGLC 28

BERKELEY, CA 6-12 JULY 2020

28th ANNUAL CONFERENCE OF THE
INTERNATIONAL GROUP FOR LEAN CONSTRUCTION

Method

Site implementation

- The real-time tracking system was implemented on the second floor at the north corner of the building where the MEP workers were scheduled to conduct pipeline-assembling task at the location
- The second floor is a big indoor open workspace (figure on the right) with a regular grid of load-bearing pillars (nine meters away from each other), and the task of pipeline-assembling should proceed following the regular direction of continuous work



The tracking system

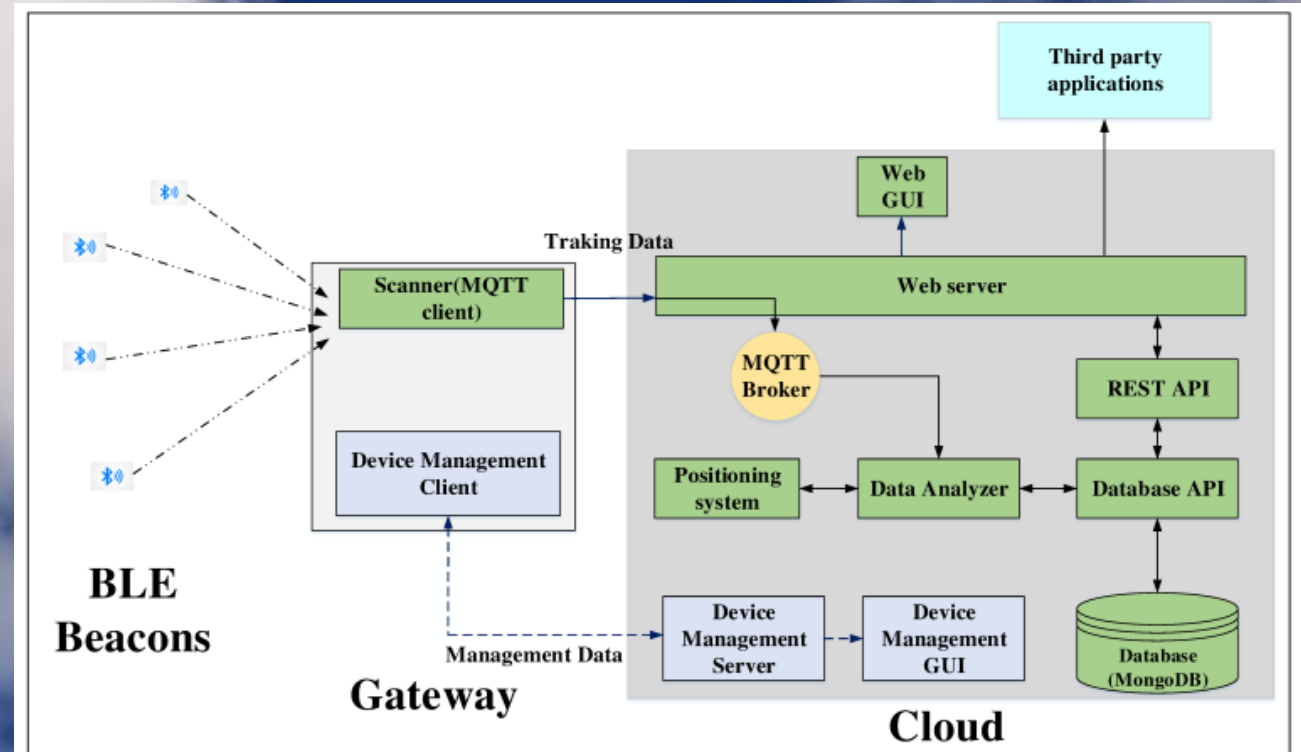


Gateways



Beacon

- BLE-tracking system with beacons and gateways
- BLE beacons, which transmit data using Bluetooth Low Energy radio technology
- Gateways, which are intermediate entities that collect data from beacons, aggregate and finally send them to the cloud. The data is transmitted in one second time interval.
- Cloud, which is the brain of the tracking system and comprises of different modules. The cloud receives all the data using MQTT (Message Queuing Telemetry Transport) protocol.





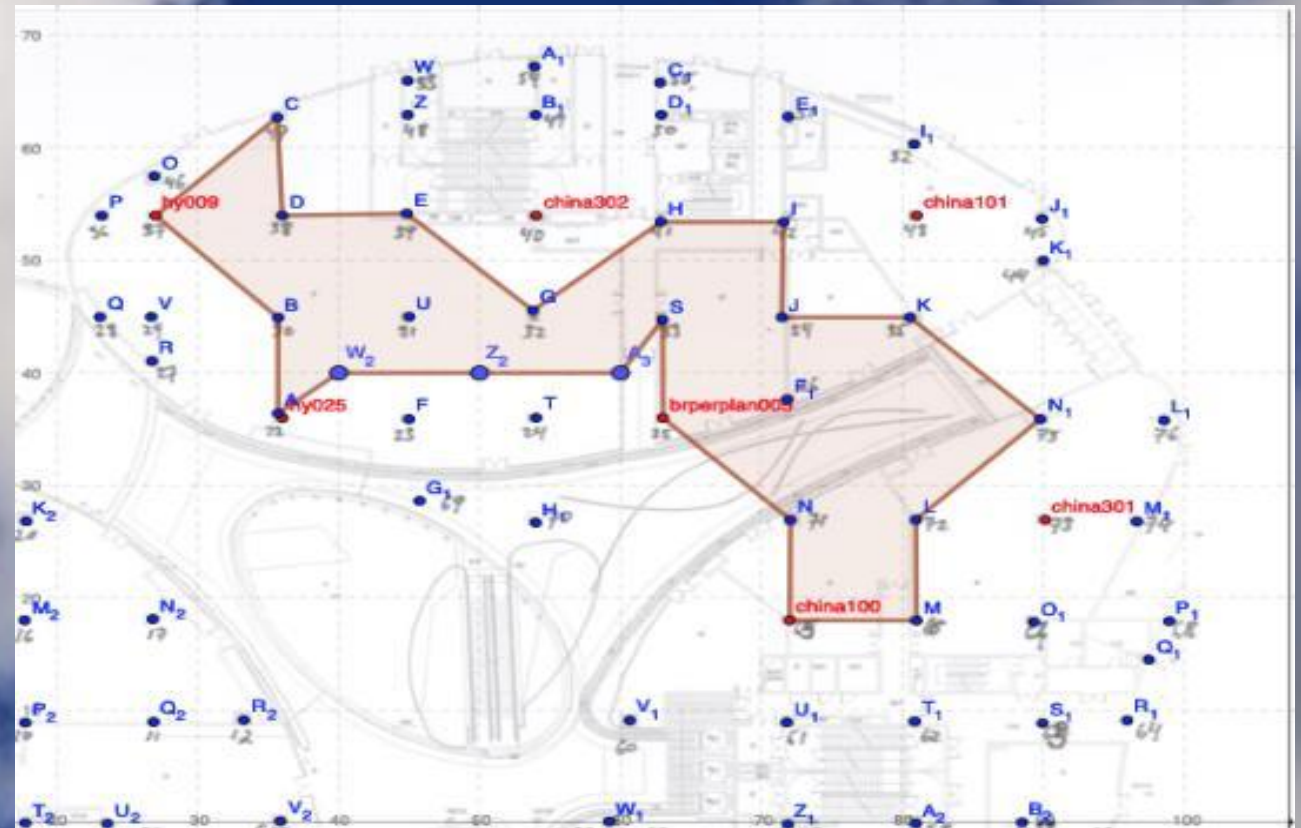
IGLC 28

BERKELEY, CA 6-12 JULY 2020

28th ANNUAL CONFERENCE OF THE
INTERNATIONAL GROUP FOR LEAN CONSTRUCTION

Onsite gateway placement and validation routine

- Seven gateways onsite and attach them to the building pillars approximately 1.5 meters above the floor. Each adjacent pillar is nine meters away from each other therefore an ideal coordinate-integrated floorplan can be modelled.
- The red dots in the figure were the validation routine where a researcher simulated a worker's possible onsite path and compared the coordinates of each test point along the path with the system-captured records.



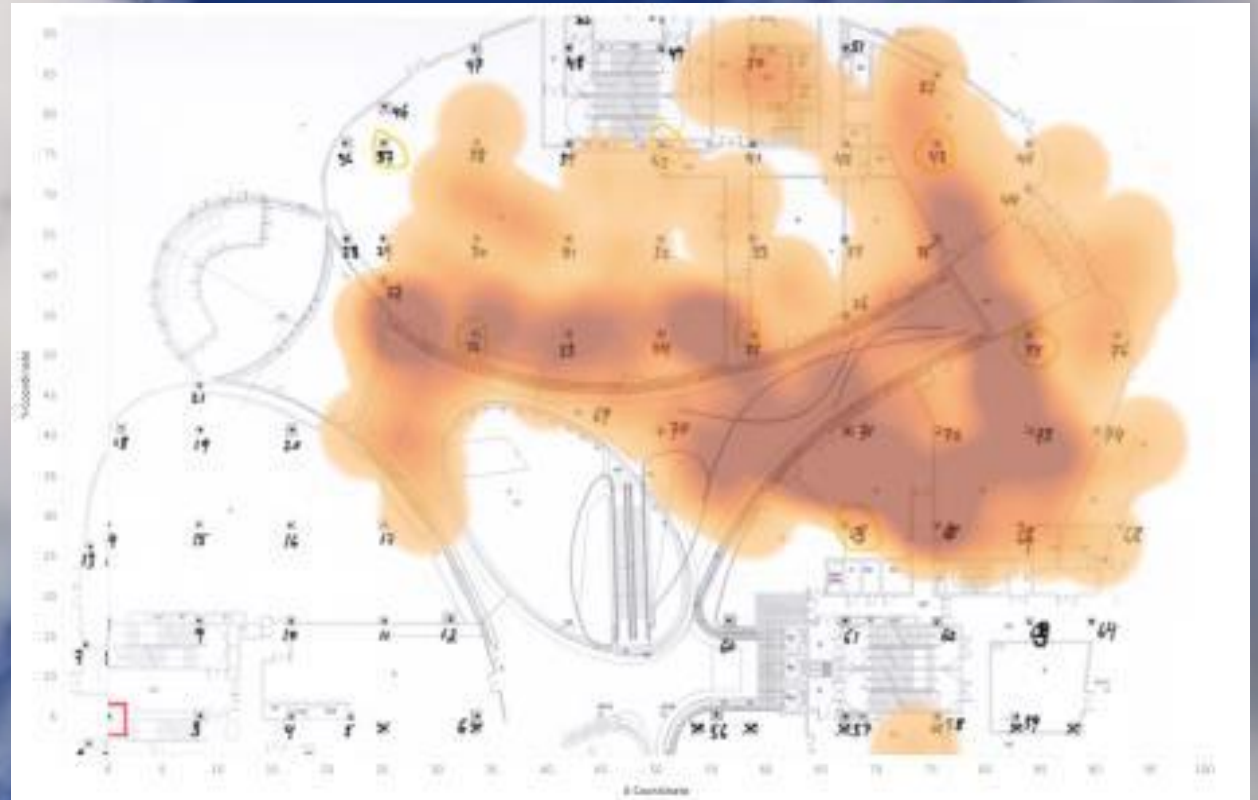
Validation results of a single coordinate detection

- Validation results based on three different measurement intervals on each test point along the path (30 second, 1 minute and 2 minutes). The measurement intervals refer to the time the researcher purposely has stayed at each test point before moving to the next point.
- The lowest average deviation between actual test points and system-captured coordinates is more than 10 meters away and this is more than one pillar away in real situation.

Validation measurement intervals	X-coordinate correlation	Y-coordinate correlation	Average deviation of all recorded points (m)	Standard deviation of all recorded points (m)
2 min	0.86	0.81	10.69	6.72
1 min	0.67	0.71	14.06	9.71
30 sec	0.74	0.35	19.18	11.62

The heat map of the validation movement routine

- Single dot of coordinate detection by the tracking system is not accurate. However, it is possible to reduce the movement from heat-map generation.
- For heat map generation, multiple points are generated per second to pinpoint the coordinate of the actual point in the system.
- More generated points as they are closer to the actual point, which makes higher density of the points in the figure.
- Therefore, deeper-colored area (higher density) is of greater probability to reflect the real place of a worker at a given time.



Results

The heat map with hourly intervals

- The heat map with hourly intervals can easily identify which hour of the day could be the workers' most likely-to-work time based on their movement density onsite. For instance, figure 7 is a heat-map change figure on May 30, 2019 onsite for MEP worker 16.
- The worker was detected for intensive onsite presence between 9am to 11am at the east corner of the test site, and between 2pm to 4pm at the middle and east corner of the test site, while he was out of site between 12pm to 1pm.
- Heat maps to fast check workers' workspace in different hours.

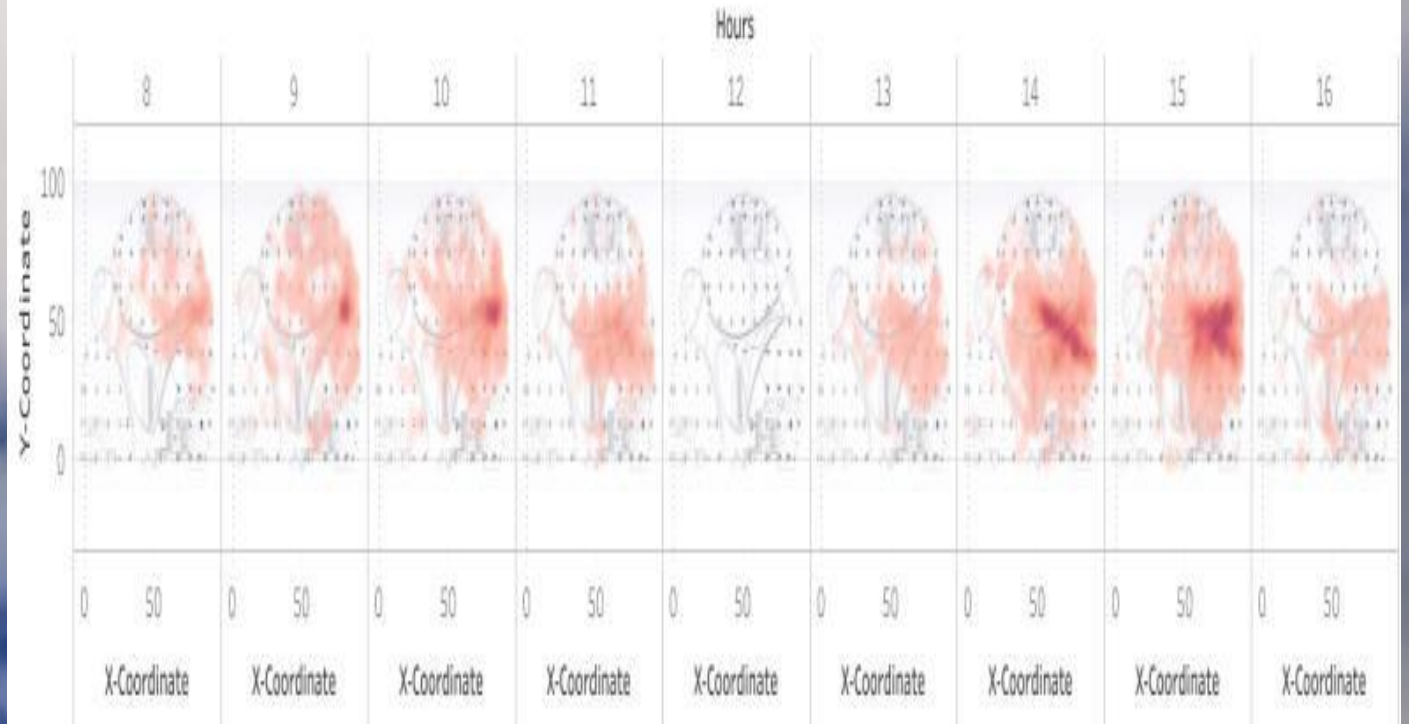


IGLC 28

BERKELEY, CA 6-12 JULY 2020

28th ANNUAL CONFERENCE OF THE
INTERNATIONAL GROUP FOR LEAN CONSTRUCTION

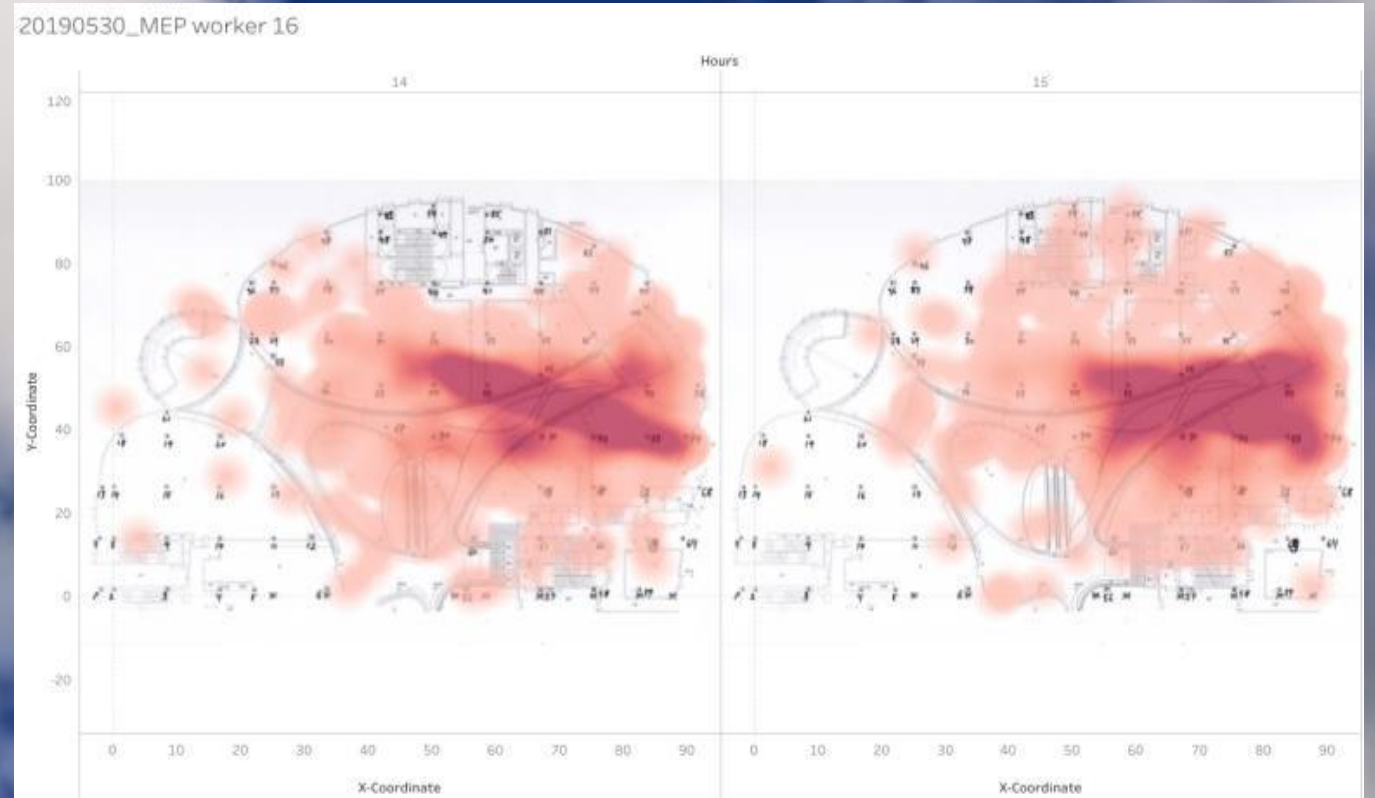
20190530_MEP worker 16



Results

Heat maps in details

- The figure on the right demonstrates the captured workspace where one MEP worker has conducted his task between 2pm to 4pm with high level of uninterrupted presence detected during this time.
- It is reasonable to think that with deeper color of the heat map, the worker is more likely to conduct value-adding activities because higher frequency of position points is detected within the deeper-colored area.
- Heat maps connect dimensional and temporal data and integrate them into real-time tracking system



IGLC 28

BERKELEY, CA 6-12 JULY 2020

28th ANNUAL CONFERENCE OF THE
INTERNATIONAL GROUP FOR LEAN CONSTRUCTION

Use cases of heat map application



IGLC 28

BERKELEY, CA 6-12 JULY 2020

28th ANNUAL CONFERENCE OF THE
INTERNATIONAL GROUP FOR LEAN CONSTRUCTION

- Analyzing takt areas.
- Identifying threshold values for workers' presence in workspace.
- Forecasting potential workspace congestion.



IGLC 28

BERKELEY, CA 6-12 JULY 2020

28th ANNUAL CONFERENCE OF THE
INTERNATIONAL GROUP FOR LEAN CONSTRUCTION

Implication

- Our findings indicate that it can provide both dimensional and temporal data through an automated and illustrative process in the construction environment that has often been characterized as chaotic.
- Heat maps that contains spatiotemporal data can generate a more straightforward space-loaded production model where value-adding activities can be potentially detected.
- Single detected point with coordinate onsite is subject to system inaccuracy and variation, but heat maps can build a fuzzy outline to estimate workspace based on the density of onsite uninterrupted presence.

Limitation and outlook



IGLC 28

BERKELEY, CA 6-12 JULY 2020

28th ANNUAL CONFERENCE OF THE
INTERNATIONAL GROUP FOR LEAN CONSTRUCTION

- System inaccuracy for the detection of coordinates. However, we think the results based on this accuracy can provide a pilot dataset to analyse the proposed use cases in the paper for lean purposes.
- What has actually happened onsite remains unknown only based on heat maps. Therefore, a more advanced positioning system featured with more accurate coordinate detection should be applied in future research, such as vision-based technologies.

Conclusion



IGLC 28

BERKELEY, CA 6-12 JULY 2020

28th ANNUAL CONFERENCE OF THE
INTERNATIONAL GROUP FOR LEAN CONSTRUCTION

- A case study where a BLE based real-time tracking system is implemented to capture workers' coordinate data in a construction site.
- Followed by onsite system implementation, coordinate detection, validation process, heat map generation and use proposals of heat maps.
- The heat map generation can outline an estimate of workspace with fuzzy borders, and three use cases were proposed.

Thank you!

Contact: Jianyu.zhao@aalto.fi



IGLC 28

BERKELEY, CA 6-12 JULY 2020

28th ANNUAL CONFERENCE OF THE
INTERNATIONAL GROUP FOR LEAN CONSTRUCTION