



# USING 5D models and CBA for planning the foundations and concrete structure stages of a complex office building

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# Background and context

## Commonly adopted methodologies by building contractors in Peru:

**Last Planner System**, which is one of the *most widely accepted techniques* by construction companies that are starting to adopt the Lean Construction. (Orihuela 2015)

**BIM** is being rapidly adopted in the Peruvian industry, a study conducted in 2017 showed that *1 out of 4 building projects in Peru used BIM*. Commonly used to improve the visualization, automate the QTO process and identify incompatibilities (Murguía 2018).

**Critical Path Method (CPM)**, which is mentioned as a contractual tool in the Peruvian government contracting laws. (Brioso et al. 2016)



# Introduction

Two **main problems** in the Contractor's traditional methodologies, tools, and procedures:

1. **Lack of synergy** between planning and control methodology of the Contractor (CPM) and Lean Construction philosophy.
2. **Lack of integration** within the tools/procedures used for methodologies that has explicit synergy.





# Introduction

## 1. Lack of synergy



### Reasons:

- **PUSH control type.** (Seppänen 2009).
- Downsides of **the controlling phase** of the CPM (Arditi et al. 2002; Olivieri et al. 2018) :
  - (i) not focusing on the workflow,
  - (ii) neglecting production rates,
  - (iii) omitting the work disparity in locations,
  - (iv) demoting resource management, and
  - (v) inefficient on repetitive projects.

### Methodology Proposed:



#### **Location Based Management system**

- Enables continuous workflow and aims Lean goals (Seppänen 2009).
- Transforms quantities in locations, determines reliable durations based on productivity information, makes buffers explicit, and alarms of future production problems based on its forecasts (Kenley & Seppänen 2010).

# Introduction

## 1. Lack of Integration



### Reasons:

- **BIM** mostly used 3D dimension approach (visualization, QTO, compatibilization) (Murguia 2018).
- **Activities based approach** of CPM do not integrate the location approach of construction.
- More effort and tools (unconnected software) needed to integrate the information of cost, durations and quantities.



### Methodology Proposed:

- **5D BIM models:** budget line items are associated with specific measurable features of model objects (Sacks et al. 2018).
- LBMS determines reliable durations based on productivity information and location quantities.
- **5D software** that integrates LBMS, BIM and LPS tools, exists in the market.

# Introduction



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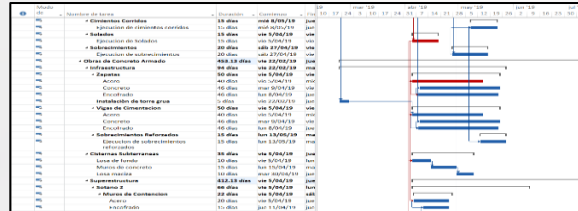
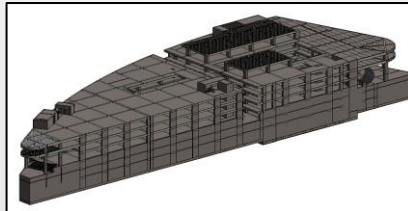
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## Traditional (current) Methodologies:

### CPM + 3D BIM model + Lean

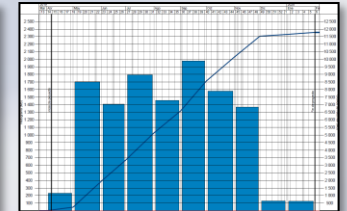
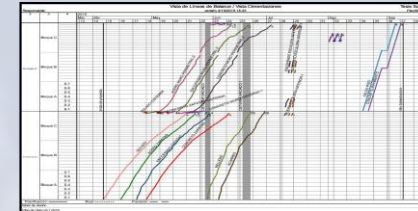
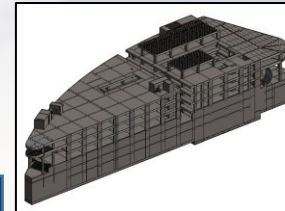
3 unconnected software



## Proposed Methodologies:

### Flowlines + 5D BIM model + Lean

1 software for 3d, cost & Schedule information



**Choosing by Advantages:** to support sound decision-making using comparisons among advantages of alternatives (Arroyo et al. 2013)

The research shows the benefits of integrated scope-cost-time solution for lean management compared to traditional methods, following a standardize decision-making.

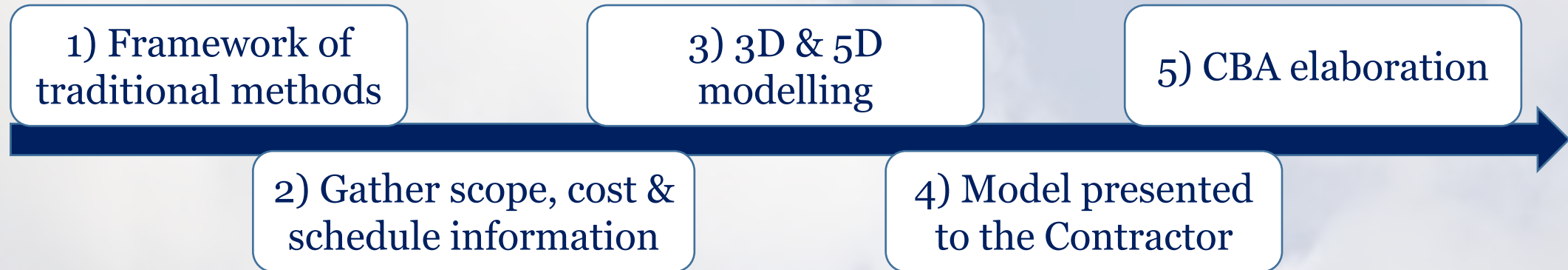




# Research Method

## Case of study:

Planning the foundations and concrete structure stages of an office building: 24 000 m<sup>2</sup> constructed area:



\*This research focuses on setting the basis in the planning phase of foundations and concrete structure, future research can cover the construction phase and other disciplines.



# 5D Model based in Flowlines

## 1) 3D modelling involved:

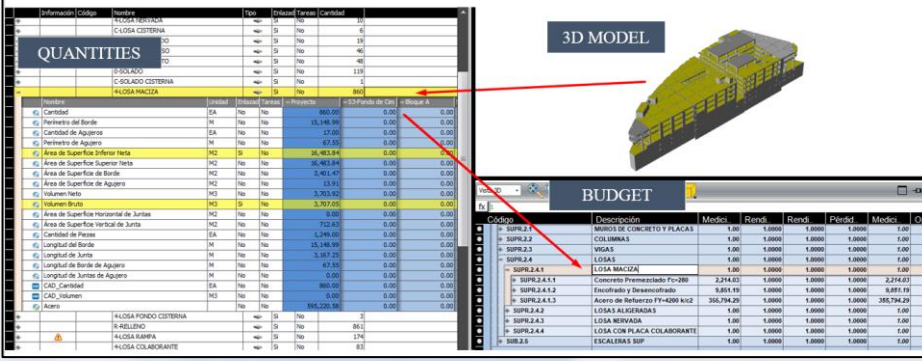
- Foundations
- Soil filling
- 4 types of slabs
- Vertical and horizontal elements
- Ramps, stairs



### 1.1) Define locations:

Floors (6) → Blocks (3 per floor) → Sectors (one per day)

## 2) Integrate 3Dmodel-locations -quantities -schedule & cost information in **one database**



The screenshot shows a software interface with a 3D model of a building structure on the right and a data table on the left. The table is divided into two main sections: 'QUANTITIES' and 'BUDGET'. The 'QUANTITIES' section lists various construction items with their respective quantities and units. The 'BUDGET' section lists the same items with their associated costs and budget values. A red arrow points from the 3D model to the 'QUANTITIES' table, indicating the integration of the 3D model with the data.

Item	Quantity	Unit	Cost	Budget
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99. CLOSA CISTERNA	1	m <sup>2</sup>	1.00	1.00
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## 3) Elaborate the flowlines





# 5D Model based in Flowlines



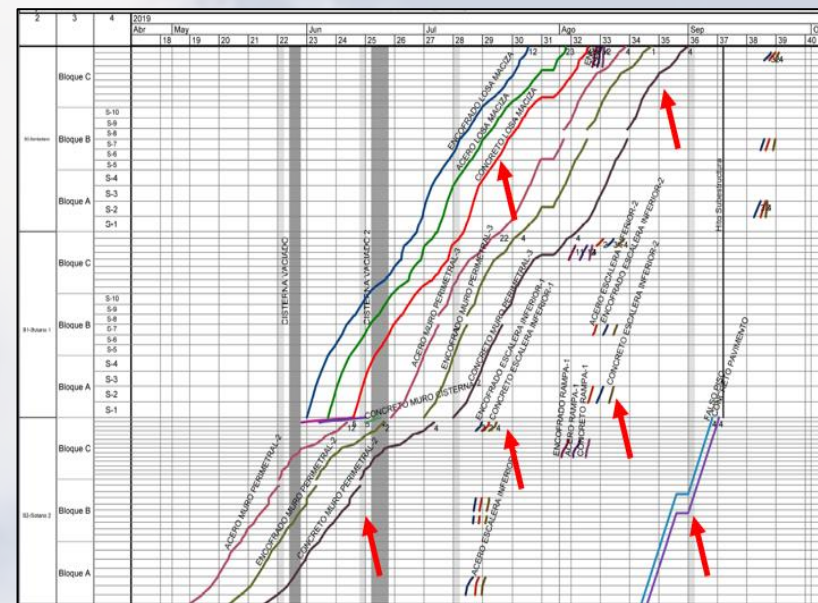
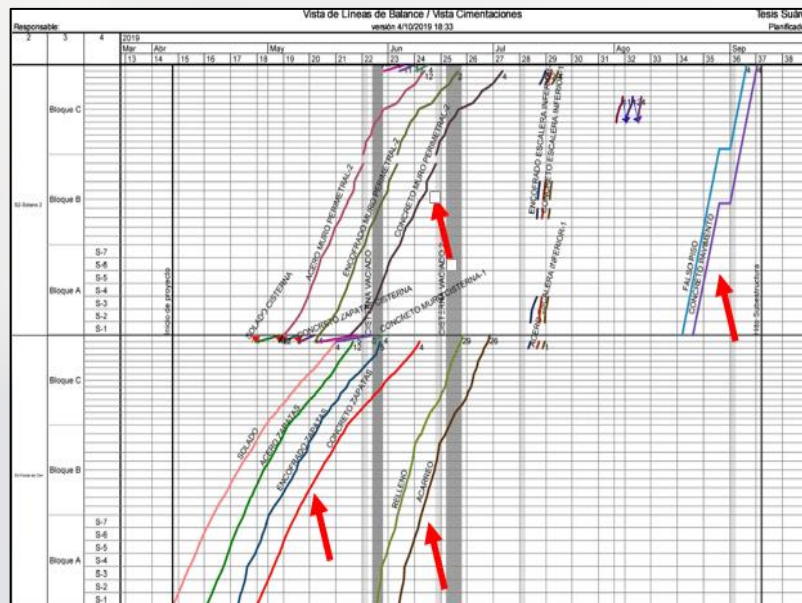
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### 3) Flowlines:

- Overview of the constructive sequence
- Identify the **bottlenecks** to ensure *continuous flows*.



**Red arrows**  
indicate the  
**bottlenecks.**

\*Concrete  
mixers were  
allowed in  
specific hours  
during the night  
shift  
\*Soil filling case





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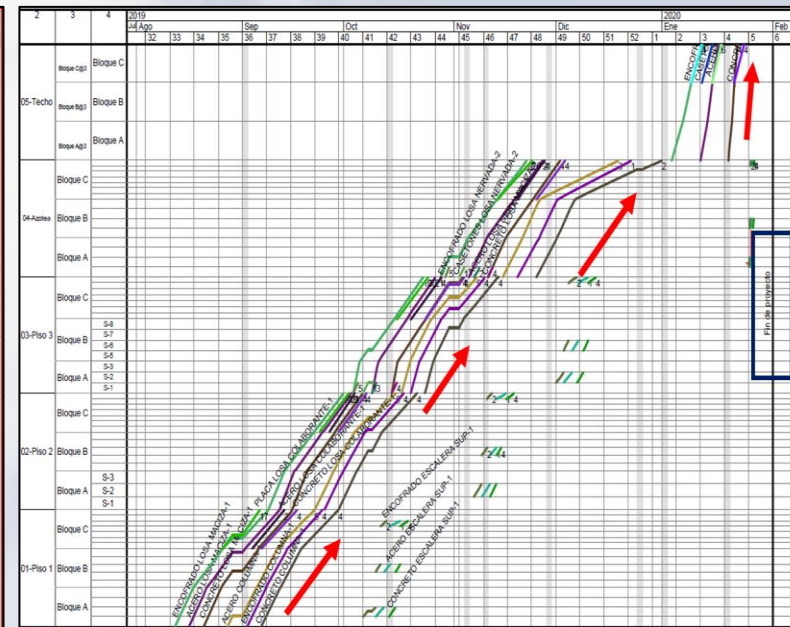
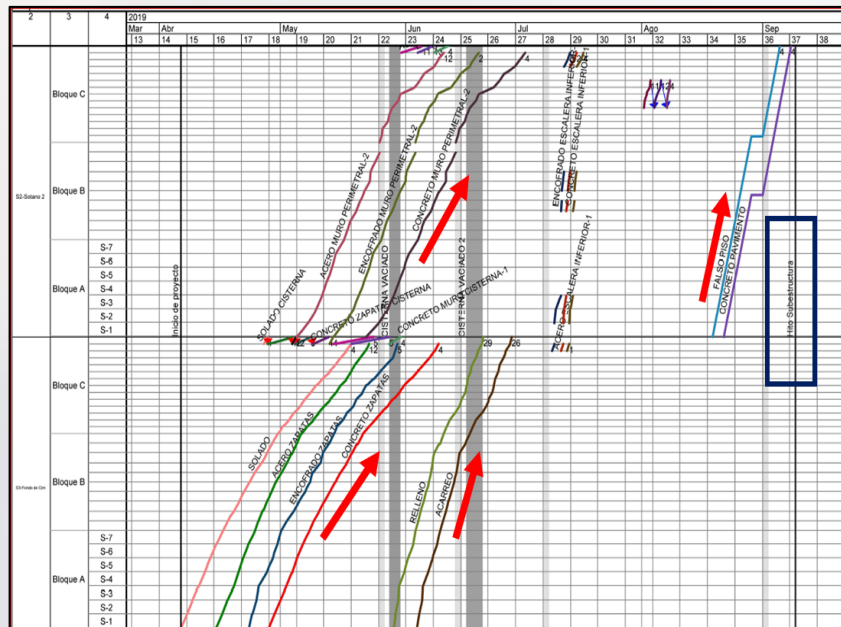
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# 5D Model based in Flowlines

## 3) Flowlines:

- Align the **slope of the bottlenecks** to the contractual milestones, plan all the activities around this slope (per location). *Efficient flows*



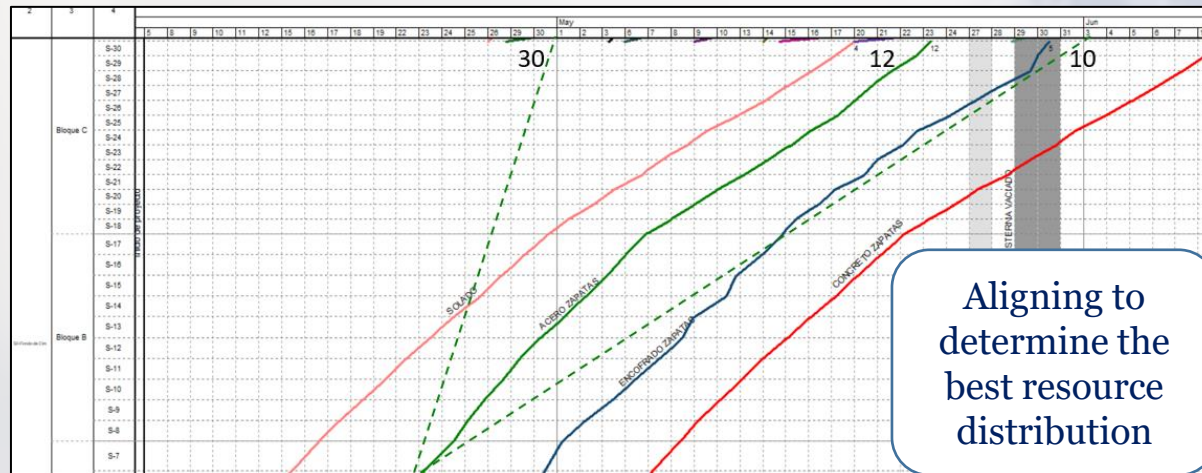
**Blue square** indicates the internal milestone  
**Red arrows** indicate the bottlenecks' slope = "Backbone"



# 5D Model based in Flowlines

## 3) Flowlines:

- When adjusting the slope of all the activities, identify **opportunities to improve** the planned resources. *Efficient processes*



### 2 problems identified

(1) **Rebar** needed more than 20 crews to achieve the production demanded.

Solution: preformed rebar

(2) **Soil filling** needed lots of manhours per day, critical activity for resources.

4) Automated resource and budget items histograms for all the detail needed (per time or per level of detail in cost)



# Evaluating the models

## ALTERNATIVES:

(1) 3D models + CPM + Lean, (2) 4D models + CPM + Lean, and (3) 5D models + LBMS + Lean

## Factors, attributes (Att:) and advantages (Adv:) criteria:

### FACTOR 1:

Plan an effective Lean Production System

#### **Criterion:**

Ensuring an effective Lean Production System is better



Alt. 1

0

Alt. 2

Att: CPM to plan



Alt. 3

100

Att: Flow lines to plan and balance the production rate based on the bottlenecks

*Adv: continuous flows, efficient flows and efficient processes*

### FACTOR 2:

Sinergy with Earn Value reports

#### **Criterion:**

Less time spent with more possible detail, is better



Alt. 1

0

Alt. 2

30



Alt. 3

90

Att: Spreadsheets manual integration

Att: CPM and quantities integrated

*Adv: automated QTO vs time*

Att: 5D model, Integrate flowlines, quantities per location and cost information.

*Adv: planned value automated, in control forecasts automated.*

# Evaluating the models



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### FACTOR 3:

Scheduling automation

#### *Criterion:*

Less time spent is better



Alt. 1

0

Alt. 2



Alt. 3

80

Att: CPM, input needed:  
durations and n° of crews

Att: Flow lines for the schedule

*Adv: durations and resources needed per  
activity are automated.*

### FACTOR 4:

Schedule understanding

#### *Criterion:*

Better understanding from the engineers



Alt. 1

60



Alt. 2

80

Alt. 3

0

Att: CPM for the scheduling and visualization

Att: flowlines represent  
the schedule.

*Adv: All the staff  
understands*

*Adv: Understanding  
+ visualization*

### FACTOR 5:

Learning process

#### *Criterion:*

Less training hours needed is better



Alt. 1

80

Alt. 2

50

Alt. 3

0

Att: 3D,  
spreadsheets  
and CPM

Att: 4D models,  
spreadsheets and  
CPM

Att: 5D models and  
LBMS

*Adv: Commonly used  
in Peruvian industry*

*Adv: Regularly used  
in Peruvian industry*

# Evaluating the models



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### **FACTOR 6:**

QTO and Cost in time automation

#### **Criterion:**

Less time spent and more detail capacity



#### **Alt. 1**

0

Att: Automated QTO  
Manual line-up  
process

#### **Alt. 2**

30

Att: Automated  
QTO and  
distribution in time

*Adv: schedule  
information synchronized*



#### **Alt. 3**

70

Att: Automated QTO and  
distribution in time  
associated with cost

*Adv: cost, sch and QTO  
automated and sync. Any detail*

### **FACTOR 7:**

Schedule understanding

#### **Criterion:**

More relevant information that do not  
complicates the Schedule analysis.



#### **Alt. 1**

0

Att: Gantt diagram represents the schedule

*Adv: All the staff  
understands*

#### **Alt. 2**

0

*Adv: Understanding  
+ visualization*



#### **Alt. 3**

50

Att: flowlines represent  
the schedule.

*Adv: Much more info.  
displayed,*

### **FACTOR 8:**

State contract laws

#### **Criterion:**

Easier determination and better  
visualization of the critical path is better



#### **Alt. 1**

50

Att: Gantt Diagram for controlling the  
schedule and displaying the critical path

*Adv: automated process to determine the Critical  
Path and effective visualization*



#### **Alt. 2**

50

#### **Alt. 3**

0

Att: Flow lines  
schedule for planning  
and control.



# Evaluating the models

(1) 3D models + CPM + Lean

**190**

(2) 4D models + CPM + Lean

**240**

(3) 5D models + LBMS + Lean

**390**

## Key outputs:

- Ensures an effective Lean Production System.
- Automated distribution of resources, costs and quantities.
- Automated calculation of resources and durations guided by bottlenecks and milestones.
- More detail capacity in the Schedule.

# Discussion

- Lack of synergy and integration in methodologies / tools → more working hours
- Proposed methodology: 5Dmodels + LBMS + Lean
  - Implemented in parallel into the planning stage
- Flowlines Schedule guided by the slope of the bottlenecks (backbones).
  - ready-mix concrete pouring process
  - soil filling process

# Discussion

- **CBA: 5D models based on the LBMS.**
  - *Planning an effective Lean Production system*  
Continuous flows → Identify the bottleneck per medium level location  
Efficient flows → Align activities to the Backbone  
Efficient processes → Optimize the construction process and resources
  - *Reporting the baseline automatically, more detail capacity*
  - *Automation*  
QTO process  
Resources and durations based on milestones and backbone  
Histograms and cost reports
- QTO difference < 1%



# Conclusion

- Integrated scope-cost-time (5D + LBMS ) is **the preferred** solution for lean management compared to traditional methods.
- 5D + LBMS allows
  - More automation (duration, resources, QTO, reports)
  - More essential details in visualization
  - More reliable process
- Further research for: Automated results in construction phase, automated early warnings, easier earn value control.

THANKS