

# 1º VIRTUAL DESIGN & CONSTRUCTION PROGRAM

CON CERTIFICACIÓN CIFE DE LA  
UNIVERSIDAD DE STANFORD.

## Presentación del Trabajo de Implementación VDC

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CENTRO DE INVESTIGACIÓN Y DESARROLLO EN INGENIERÍA

# VDC Methodology Applied to the Design of Civil Engineering Laboratories

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**Title:** VDC Methodology applied to the Conceptual Design of Civil Engineering Laboratories

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**Summary:** The VDC Framework is introduced and applied, step-by-step, for the conceptual design of the civil engineering laboratories, at the Universidad de Lima. A VDC framework is proposed, attending to the client and project objectives, including the production metrics and controllable factors. Finally, it is shown the main benefits of the VDC methodology application on this project.

**Keywords:** Virtual Design and Construction, VDC, Integrating Project Delivery, IPD, BIM, Integrated Concurrent Engineering, Project Production Management, Production Objectives, Controllable Factor, Metrics.

**Note:** This presentation was realized as part of the VDC Program 2019-2020 of the Center for Integrated Facility Engineering (Stanford University) in collaboration with the Universidad de Lima.

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# Summary of the Project

- The Civil Engineering Laboratories of the Universidad de Lima has an area of 1,440 m<sup>2</sup> and were built in 2017 for a budget of \$20M approximately.
- The laboratories are:
  1. Environmental Engineering,
  2. Geotechnical,
  3. Hydraulics,
  4. Hydrology,
  5. Materials,
  6. Pavements,
  7. Sanitary Engineering,
  8. Structures,
  9. Topography and Geomatics.

Due to the limited space available to install the equipment for six laboratories (Structures, Environmental Engineering, Pavements, Sanitary Engineering, Hydraulics, and Hydrology), a detailed plan was developed, supported by the VDC methodology, to avoid unforeseen issues during installation and operation of pieces of equipment.



# Summary of the VDC Implementation

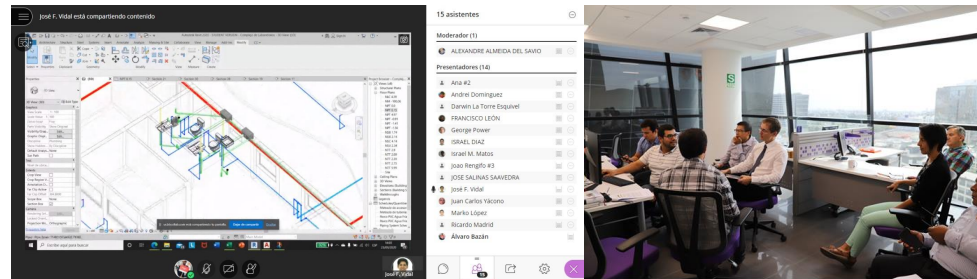
## Client Objective (CO):

- Buy the laboratory equipment by the end of July 2021.



## Project Objective (PO):

- Make de the purchase order for the laboratory equipment by December 30th, 2020.
- Have the infrastructure of the new laboratories, including the equipment, virtually integrated with the existing infrastructure at 100%.

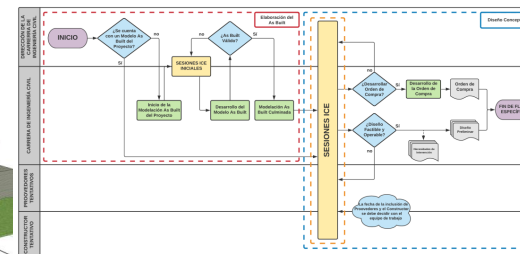
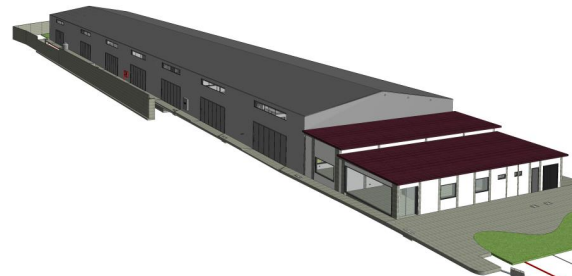


## ICE:

- Collaboratively resolve all the issues (interferences, pending issues, and conflicts) that may exist between the laboratories and the equipment that will be installed.

## BIM:

- Build a BIM model with the Structures, Sanitary, Electrical and Architecture disciplines of the project and integrate the laboratory equipment.



## PPM:

- Reduce variability per month in the resolution of issues and the fulfillment of planned objectives, respectively.

# Summary of the VDC Implementation

## Cumulative Current Results per Session<sup>(1)</sup>

17 solved issues  
out of 49

%SI<sup>(2)</sup> = 35%

Target Performance

%SI<sup>(2)</sup> = 100%

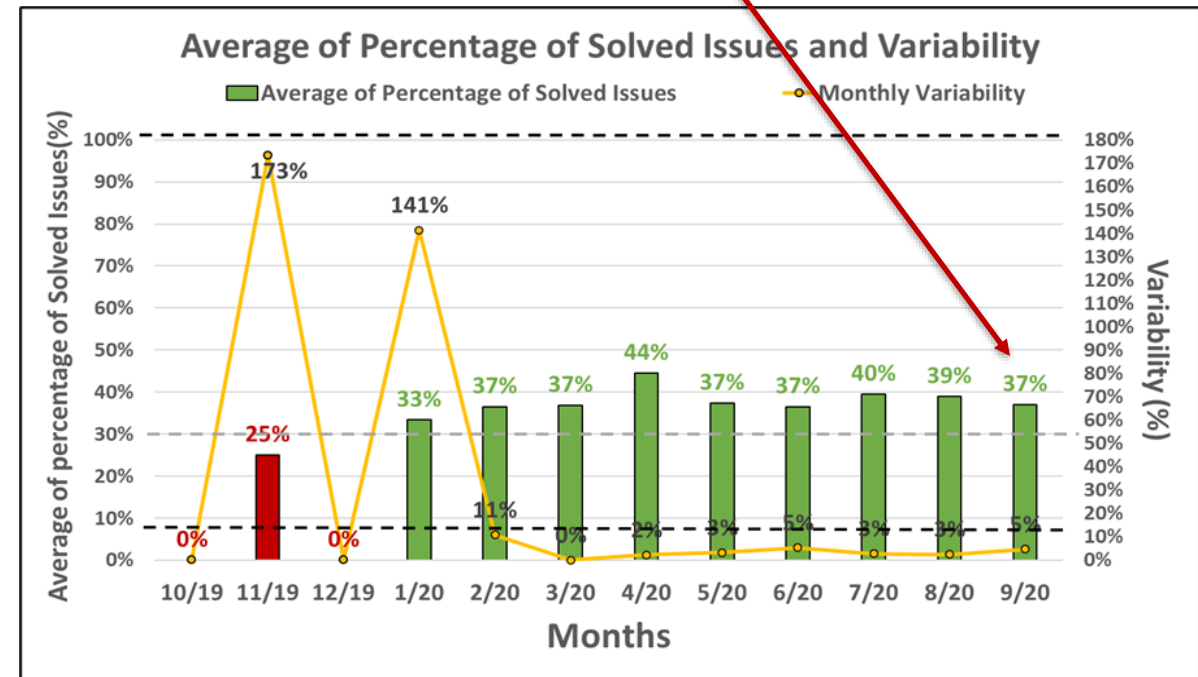
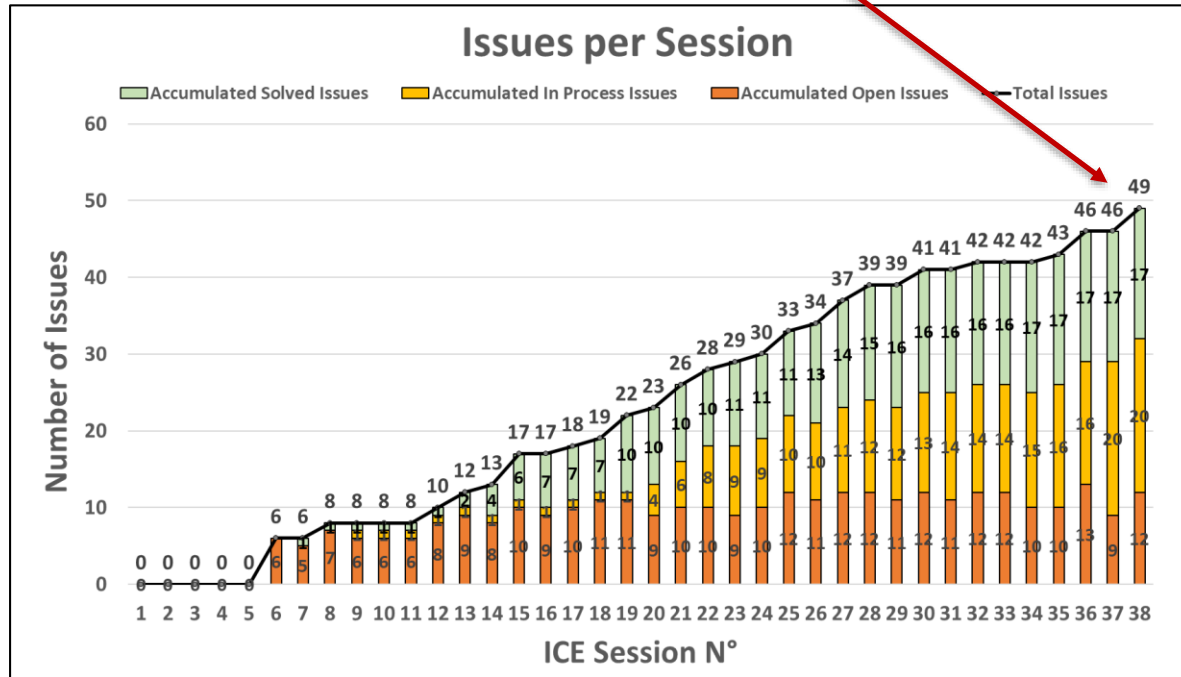
## Cumulative Current Results per Months<sup>(1)</sup>

September  
%IS<sup>(2)</sup> = 37%

$\Delta$ SI%<sup>(3)</sup> = 15%

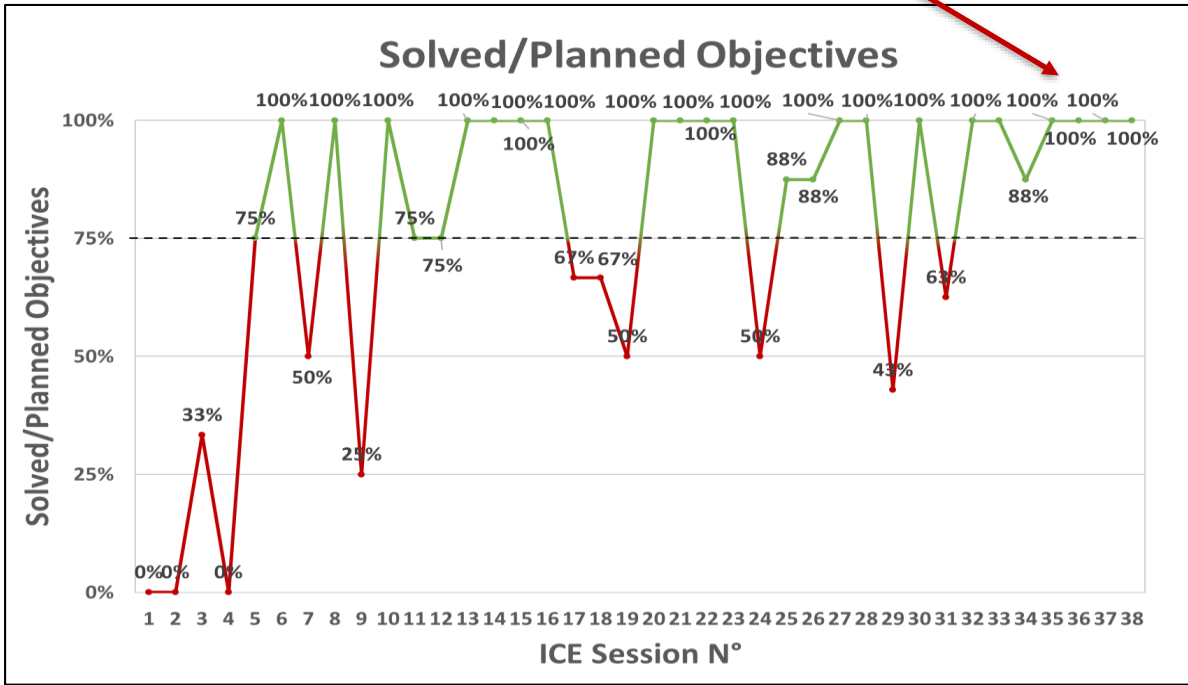
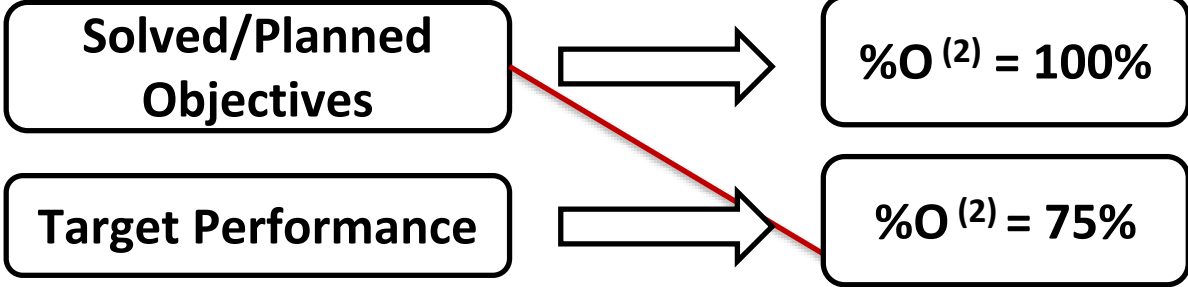
Target Performance

$\Delta$ SI%<sup>(3)</sup> < 15%

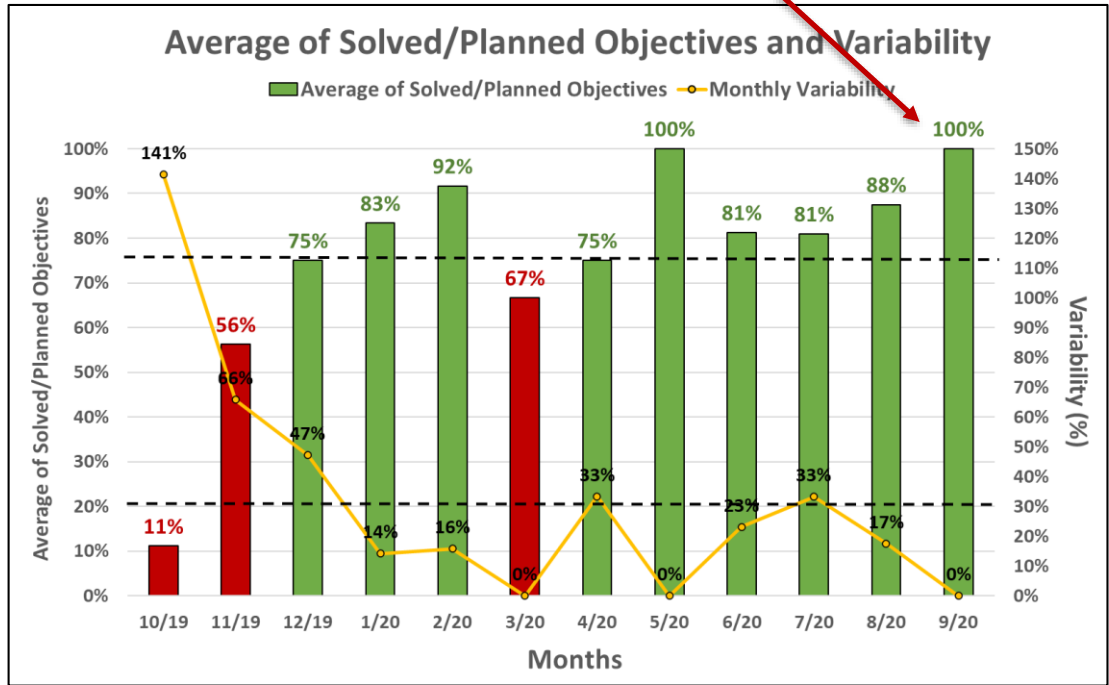
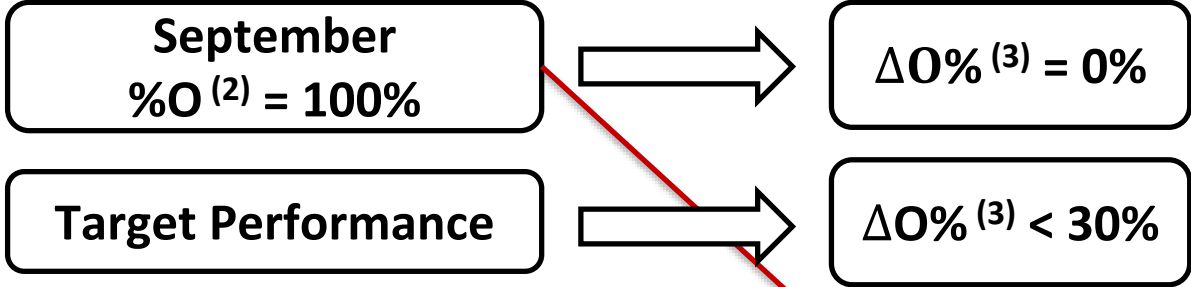


# Summary of the VDC Implementation

## Cumulative Current Results per Session<sup>(1)</sup>



## Cumulative Current Results per Months<sup>(1)</sup>



(1) Accumulated results from October 16<sup>th</sup>, 2019 to October 1<sup>st</sup>, 2020.  
 (2) %O: Solved/Planned Objectives.  
 (3) Δ%O: Variability of the Average Solved/Planned Objectives per month.



# Detailed description of the VDC application

Type of objective/metric	Objective / Metric	Target performance	Best performance achieved
Client objective	<ul style="list-style-type: none"> <li>Buy the laboratory equipment.</li> </ul>	<ul style="list-style-type: none"> <li>By the end of July 2021</li> </ul>	<ul style="list-style-type: none"> <li>-</li> </ul>
Project objective	<ul style="list-style-type: none"> <li>Make de the purchase order for the laboratory equipment.</li> <li>Have the infrastructure of the new laboratories, including the equipment, virtually integrated with the existing one.</li> </ul>	<ul style="list-style-type: none"> <li>December 30, 2020</li> <li>100%</li> </ul>	<ul style="list-style-type: none"> <li>November 30, 2020</li> <li>100%</li> </ul>
ICE Production objective	<ul style="list-style-type: none"> <li>Collaboratively resolve all the issues (interferences, pending issues and conflicts) that may exist between the laboratories and the equipment that will be installed.</li> </ul>	<ul style="list-style-type: none"> <li><math>\%SI_i^{(1)} \geq 30\%</math></li> <li><math>\%SI_f^{(2)} = 100\%</math></li> <li><math>\Delta\%SI^{(4)} &lt; 15\%</math></li> </ul>	<ul style="list-style-type: none"> <li><math>\%SI^{(3)} = 44\%</math></li> <li><math>\Delta\%SI^{(4)} = 0\%</math></li> </ul>
BIM Production objective	<ul style="list-style-type: none"> <li>Build a BIM model with the Structures, Sanitary, Electrical and Architecture disciplines of the project and integrate the laboratory equipment.</li> </ul>	<ul style="list-style-type: none"> <li><math>LOD = 350</math></li> </ul>	<ul style="list-style-type: none"> <li><math>LOD = 300</math> (work still in process)</li> </ul>
PPM Production objective	<ul style="list-style-type: none"> <li>Reduce variability per month in the resolution of issues and the fulfillment of planned objectives, respectively.</li> </ul>	<ul style="list-style-type: none"> <li><math>\%O^{(5)} \geq 75\%</math></li> <li><math>\Delta\%O^{(6)} \leq 30\%</math></li> </ul>	<ul style="list-style-type: none"> <li><math>\%O^{(5)} = 100\%</math></li> <li><math>\Delta\%O^{(6)} = 0\%</math></li> </ul>

1)  $\%SI_i$  : Initial goal for the percentage of solved issues

2)  $\%SI_f$  : Final goal for the percentage of solved issues

3)  $\%SI$ : Percentage of solved issues

4)  $\Delta\%SI$ : Variability of the average solved issues per month

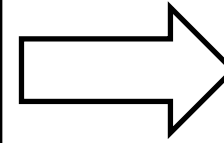
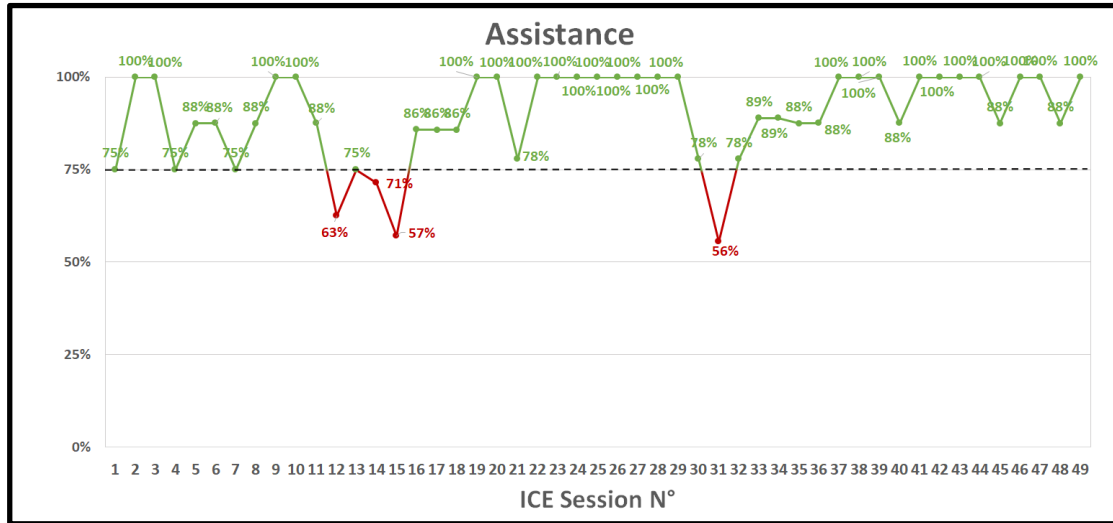
5)  $\%O$ : Solved/Planned Objectives.

6)  $\Delta\%O$ : Variability of the Average Solved/Planned Objectives per month

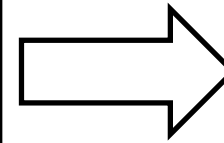
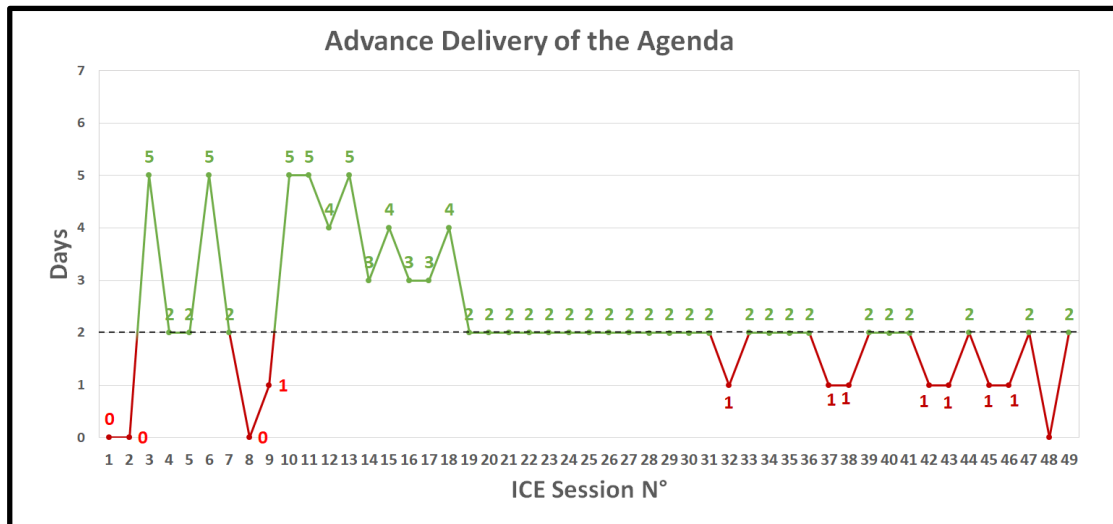
# Detailed description of the VDC application

Type of objective/metric	Objective / Metric	Target performance	Best performance achieved
ICE Controllable factor	Include the Laboratory Managers	<ul style="list-style-type: none"> <li>Assistance = 100%</li> </ul>	<ul style="list-style-type: none"> <li>Assistance = 100%</li> </ul>
BIM Controllable factor	Use online viewers to facilitate accessibility and visualization of the BIM model.	<ul style="list-style-type: none"> <li>Everyone has access</li> <li>Share the updated model viewer each week</li> </ul>	<ul style="list-style-type: none"> <li>Everyone had access</li> <li>Share the updated model viewer each week</li> </ul>
PPM Controllable factor	Include VDC enablers as capacity buffers.	<ul style="list-style-type: none"> <li>2 VDC enablers</li> </ul>	<ul style="list-style-type: none"> <li>2 VDC enablers</li> </ul>

# Results of ICE metrics and controllable factors

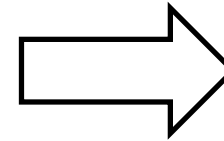
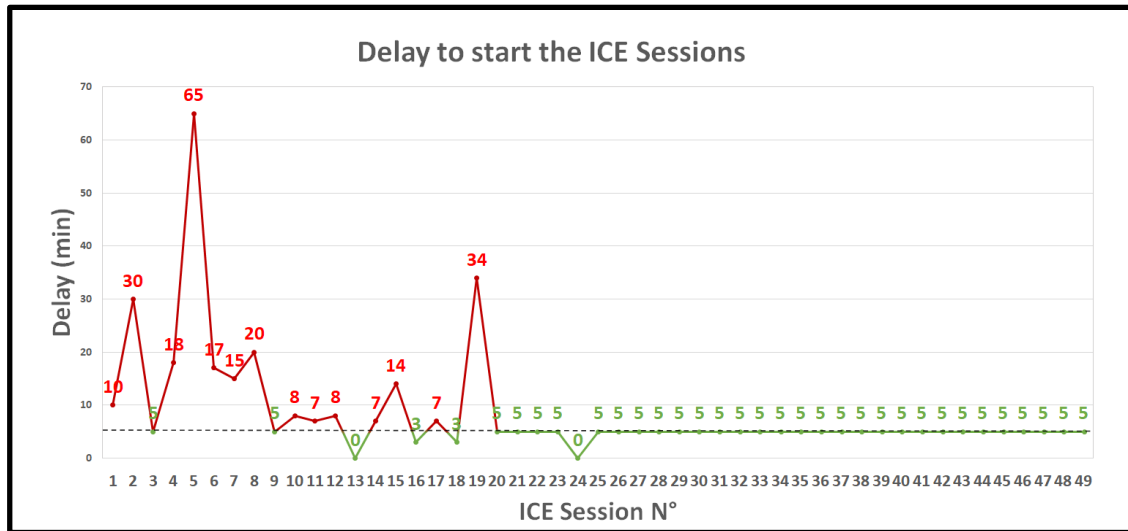


The assistance has been very above the goal of 75% since session 16. Therefore, it was considered to increase the goal to 80%.

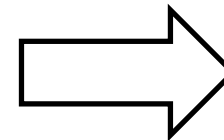
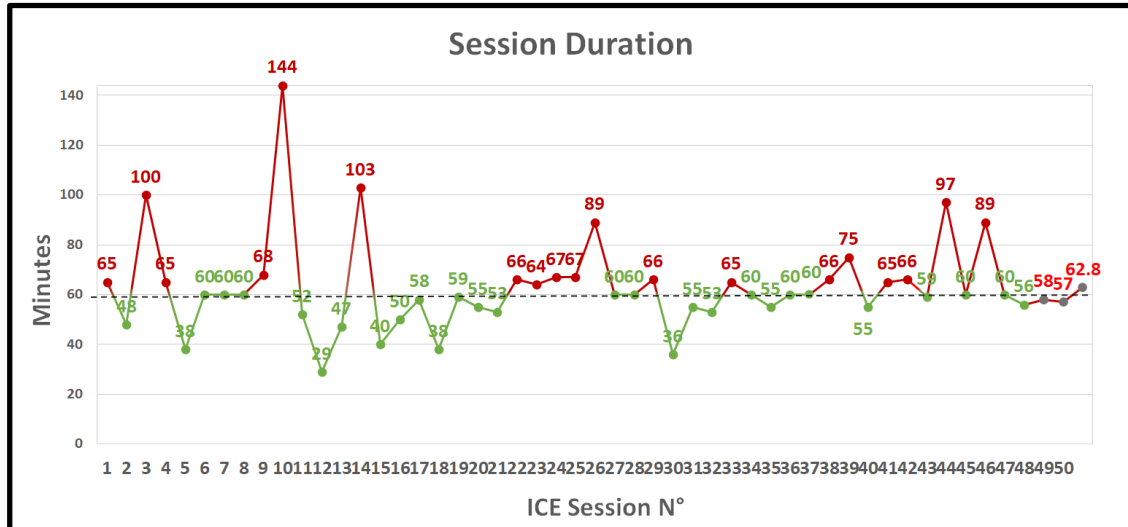


The anticipated delivery of the agenda tends to the goal of 2 days in advance. There were some outliers, but now it is working fine.

# Results of ICE metrics and controllable factors



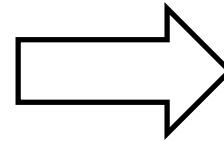
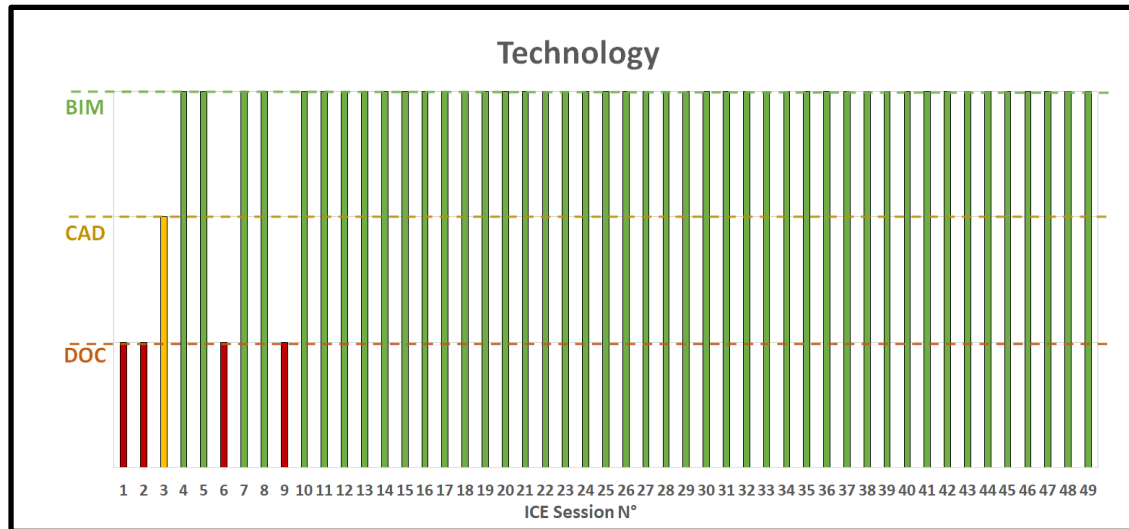
The delay to start of the session has been handled since session 20. The remote work support to reach the goal.



The duration of the sessions has been extended, with a slight improvement in the last sessions.

We are putting aside the debate between participants to comply with the time. Therefore, increasing the session duration is being evaluated.

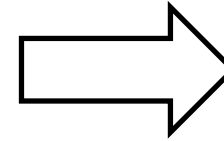
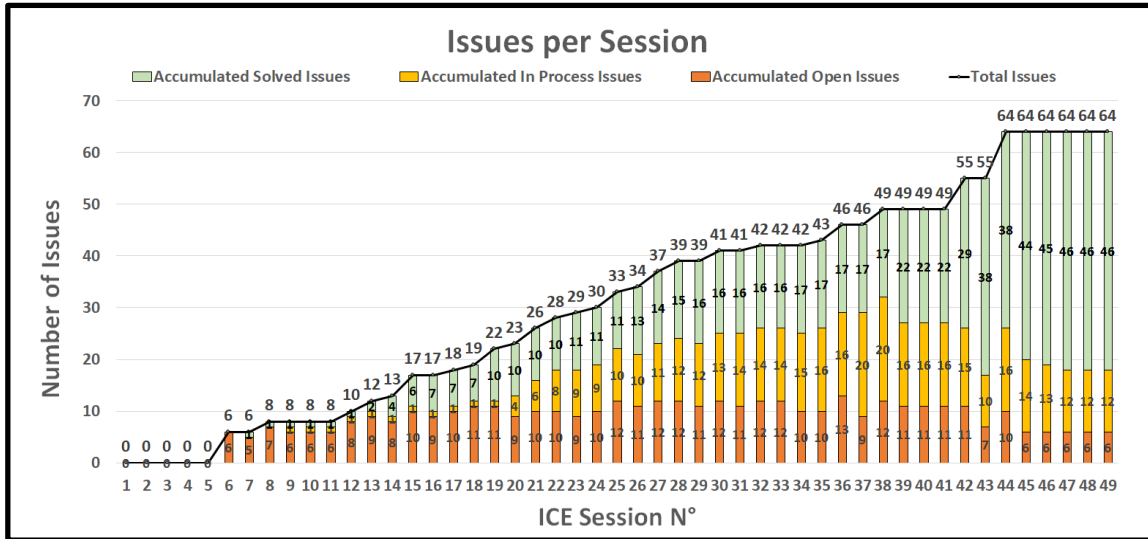
# Results of ICE metrics and controllable factors



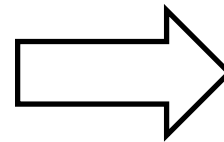
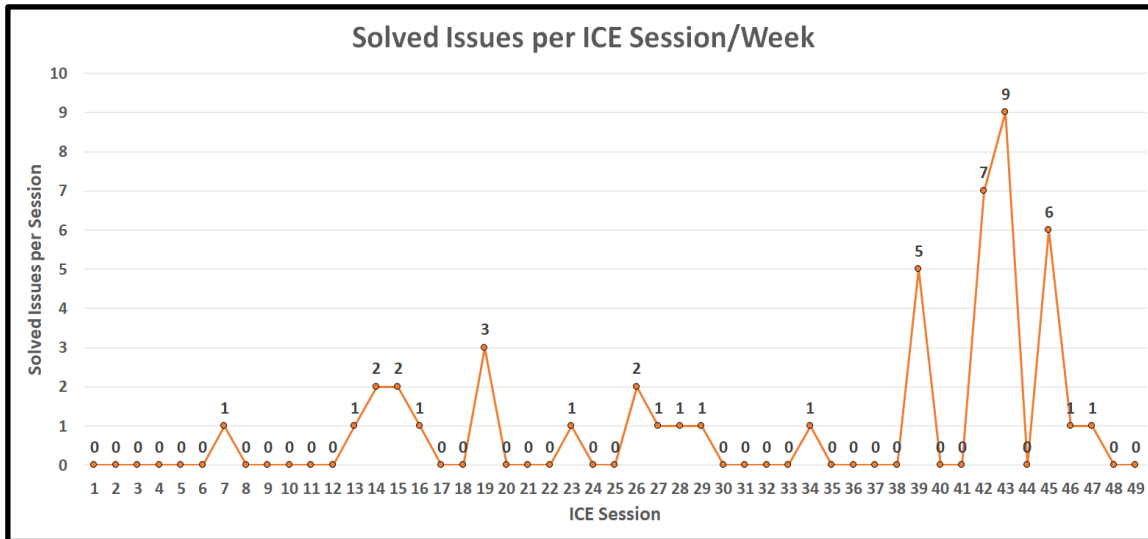
**Starting in session 10, we have continuously used BIM in ICE sessions.**

**It has become quite natural for the work team. In that sense, it is being evaluated to stop reporting this metric.**

# Results of ICE metrics and controllable factors

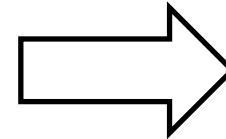
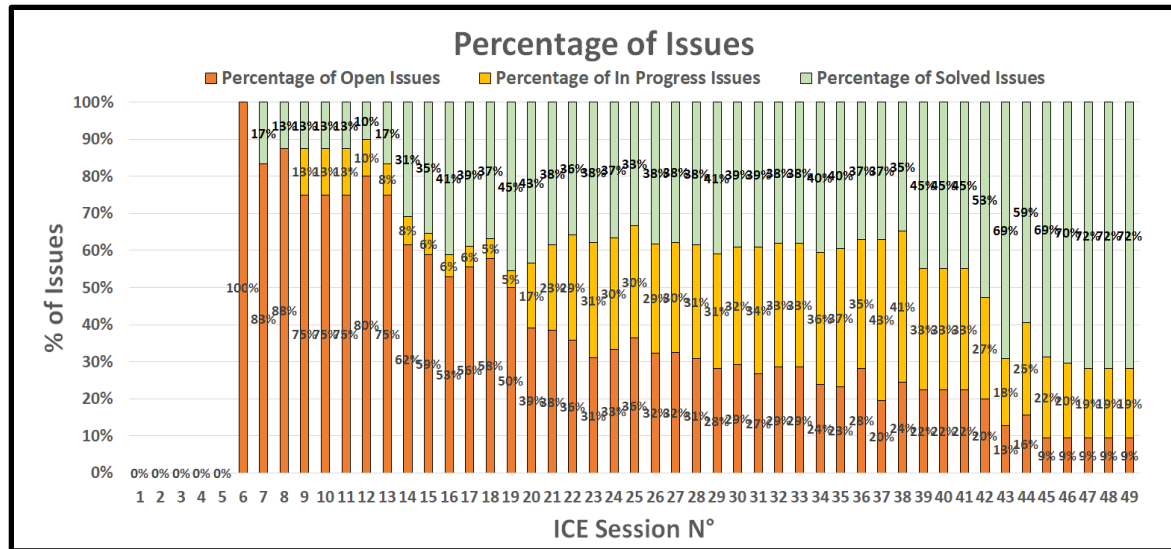


**We have started to detect many issues, and several are in the process of being solved. However, greater control must be generated to solve and close the issues that are pending.**

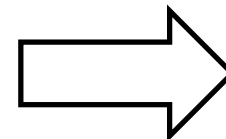
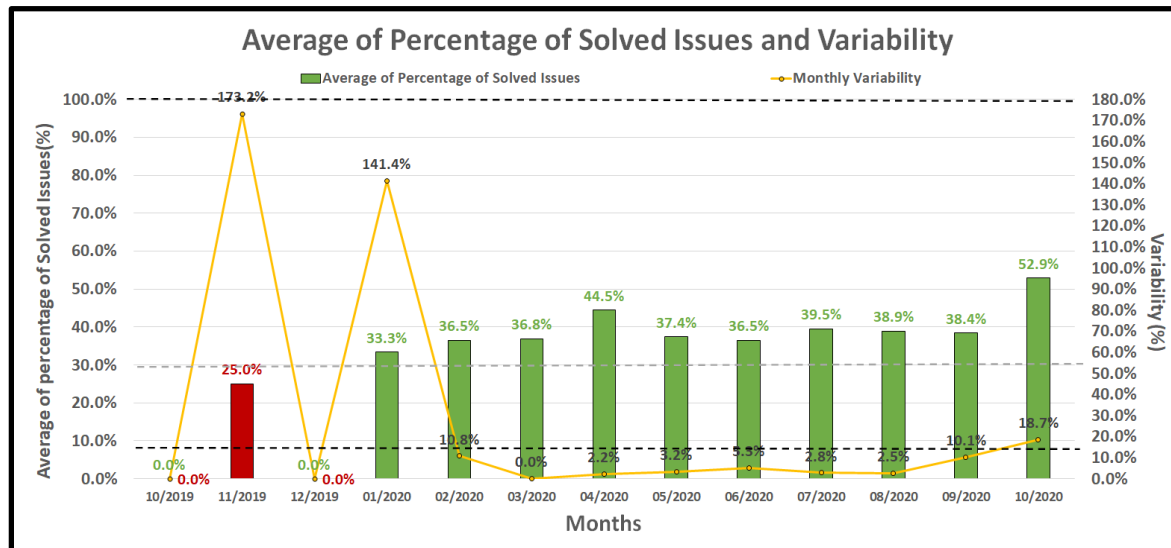


**We have had deficiencies in solving the issues within a defined time frame. This metric is relatively recent, and we are studying to establish better tools to overcome this issue.**

# Results of ICE metrics and controllable factors



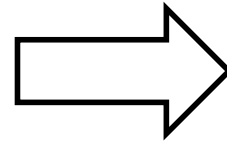
It is appreciated that we have accumulated a large number of issues in the process and open issues that are pending resolution. We decided to reinforce the follow-up of pending issues.



A stagnation is seen in the solution of issues. More issues are being identified, but they are not being solved at the same time. On the other hand, the variability is below the maximum allowed variability of this subject.

# Results of ICE metrics and controllable factors

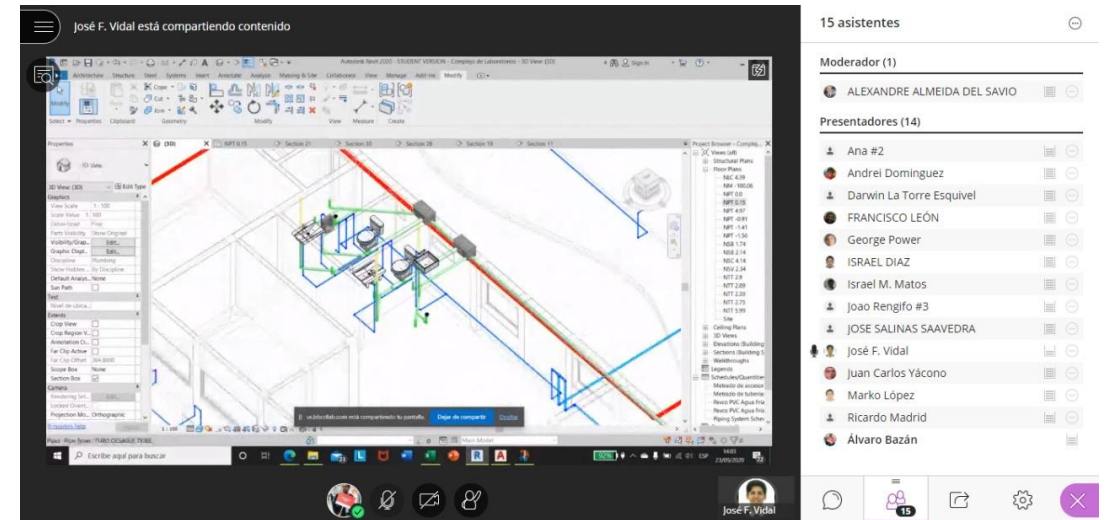
Pictures that describe the implementation



Remote ICE Sessions



ICE





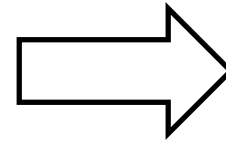
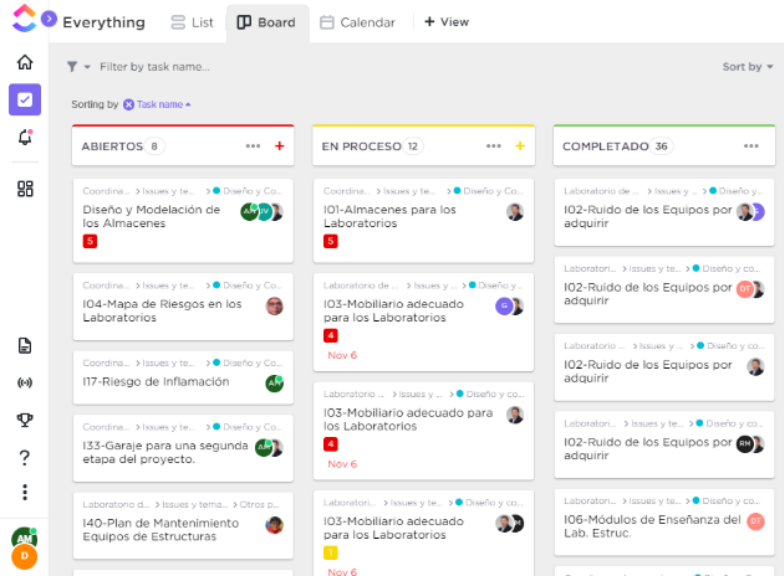
# Results of ICE metrics and controllable factors

## Issues Tracking Table

COI	Name	Date of identification	Estimated date of solution	Solution date	Action taken	Status	Responsable	Count Open	Count Process	Count Solved
I1	Warehouses for Laboratories	20/11/2019	-	-	-	Open	Por verse	0	0	0
I2	Equipment noise	20/11/2019	-	-	-	Open	Por verse	0	0	0
I3	Suitable Furniture for Laboratories	20/11/2019	-	-	Furniture for S2H, Pavements and Environmental Engineering	In Process	Responsables de los Labs.	0	0	0
I4	Map of Risks in Laboratories	20/11/2019	-	-	-	Open	Juan Yacono	0	0	0
I5	Calibration of Equipment for orders	20/11/2019	-	-	Calibration Management with Suppliers	In Process	Andrei Domínguez	0	0	0
I6	Structures Laboratory Teaching Modules	20/11/2019	27/11/2020	27/11/2020	The modules will be acquired in the second phase of implementation	Solved	Darwin La Torre	0	0	0
I7	Extractor Hood - Environmental Engineering Laboratory	4/12/2019	-	-	Communication with Suppliers - Tentative Design at BIM	In Process	Ludy Cáceres	0	0	0
I8	Communication System in Equipment	4/12/2019	-	-	-	Open	Jose Salinas y Andrei Domínguez	0	0	0
I9	Area for Controlled Temperature	15/01/2020	5/02/2020	5/02/2020	Inclusion of the Area	Solved	Álvaro Bazán, Ludy Cáceres y Ricardo Madrid	0	0	0
I10	Shower and Safety Eye Wash	15/01/2020	13/02/2020	13/02/2020	Inclusion of the eye washer and Shower Room	Solved	Álvaro Bazán y Ludy Cáceres	0	0	0
I11	Equipment above the drainage channels	22/01/2020	5/02/2020	5/02/2020	Moving Equipment	Solved	Álvaro Bazán	0	0	0

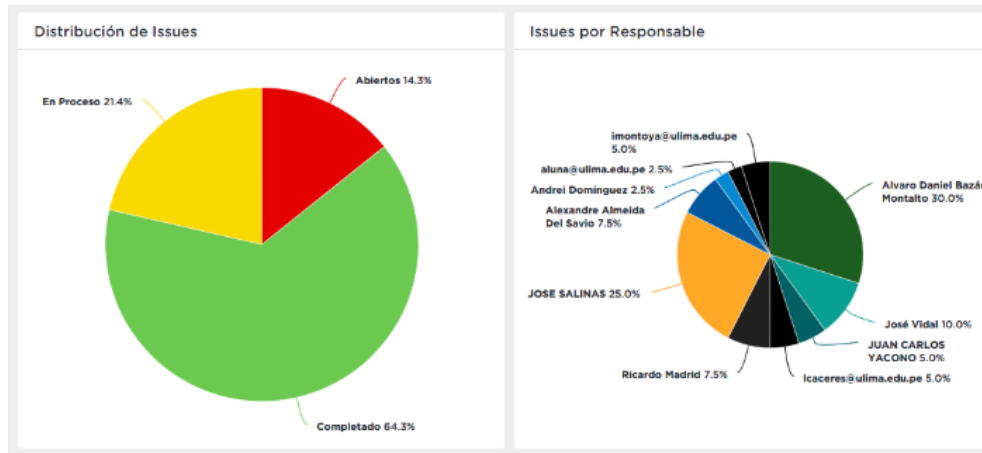
# Results of ICE metrics and controllable factors

## Monitoring of Issues in the “Click up” Platform

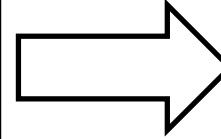
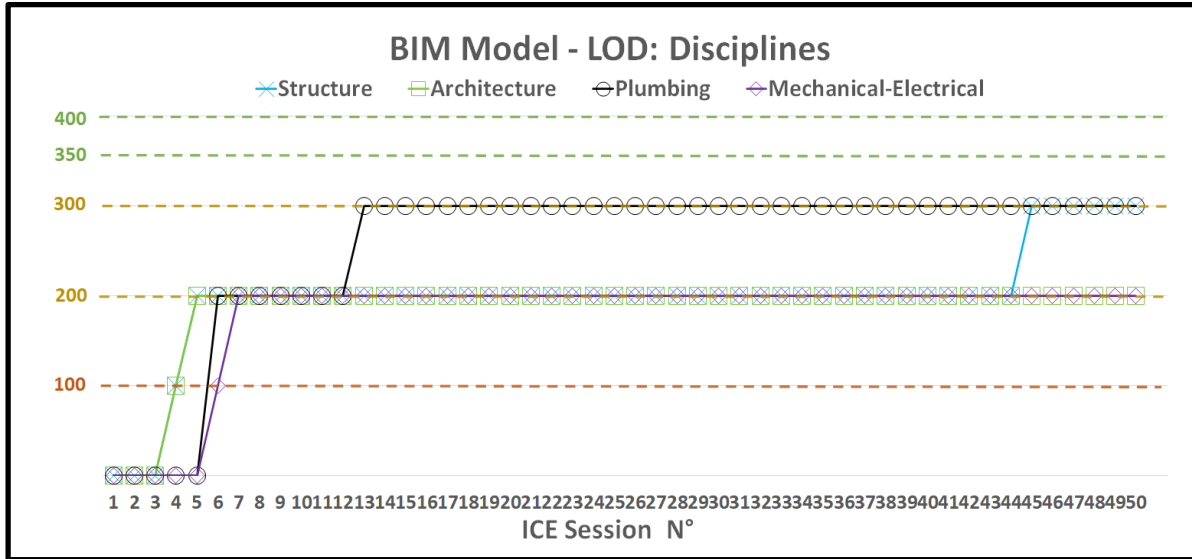


From session 38 onwards, we decided to use an online platform called “Click up,” which allowed us to conduct a better follow-up on pending issues.

Thus, the environment was organized, and the pending issues were divided by the person in charge. In addition, they allowed the creation of sub-tasks to measure the degree of progress of each pending issue.



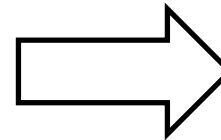
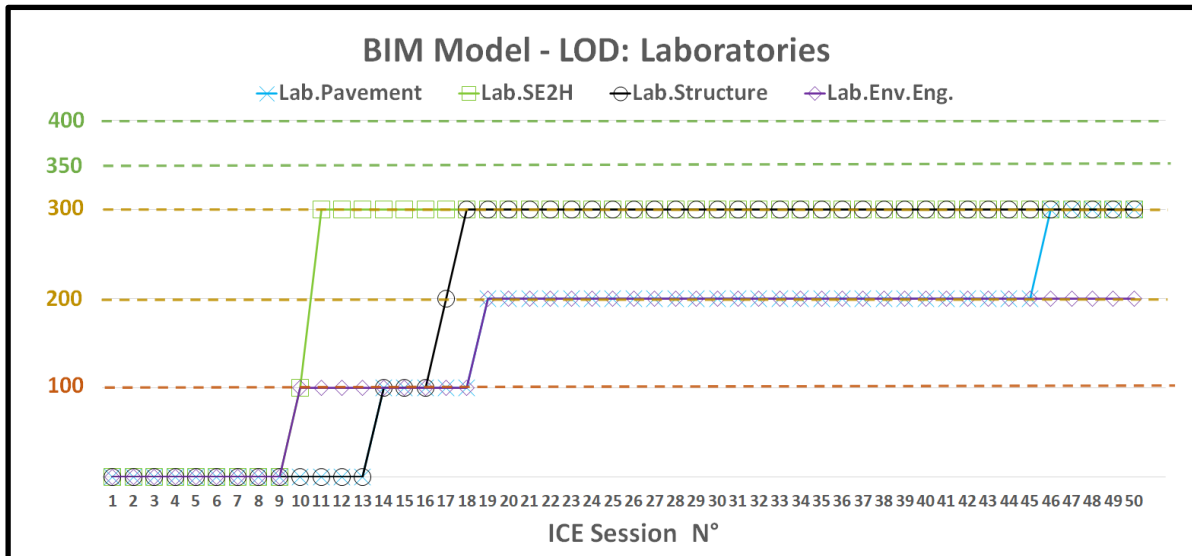
# Results of BIM metrics and controllable factors



All the information available for the elaboration of the As built has been modeled.

It is very likely that the LOD cannot be increased without generating additional effort.

Modifying the goal for each of the specialties is being evaluated.



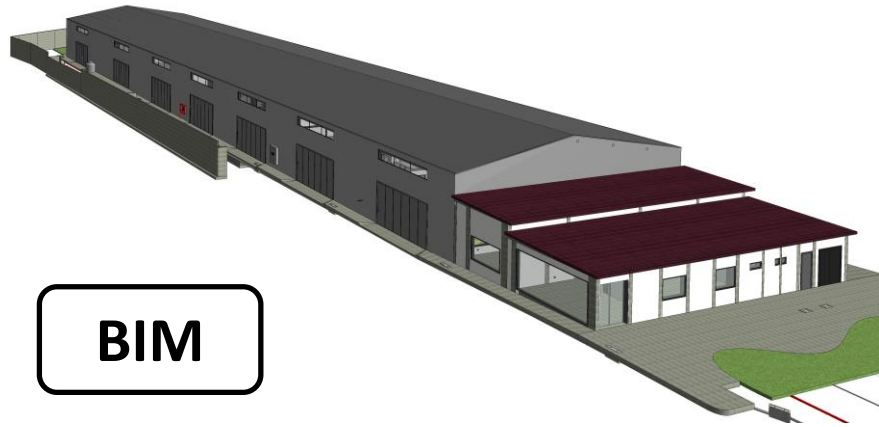
All the information available to the laboratories has been modeled.

In some laboratories, BIM models provided by suppliers have been included.

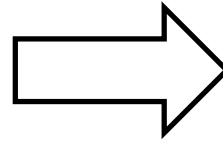
This allowed increasing the LOD.

# Results of BIM metrics and controllable factors

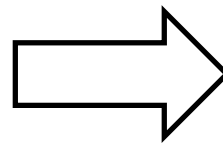
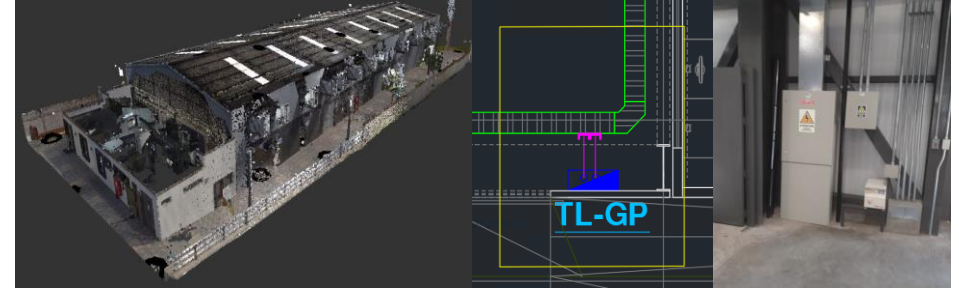
Pictures that describe the implementation



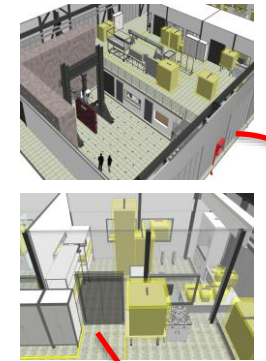
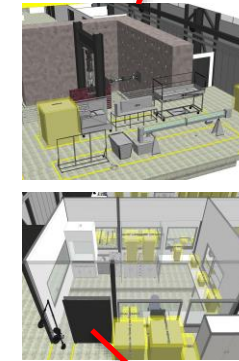
**BIM**



**As Built Model**



**Conceptual Desing**



**S2H\*  
Laboratory**

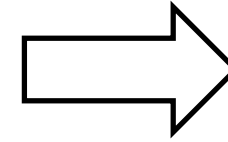
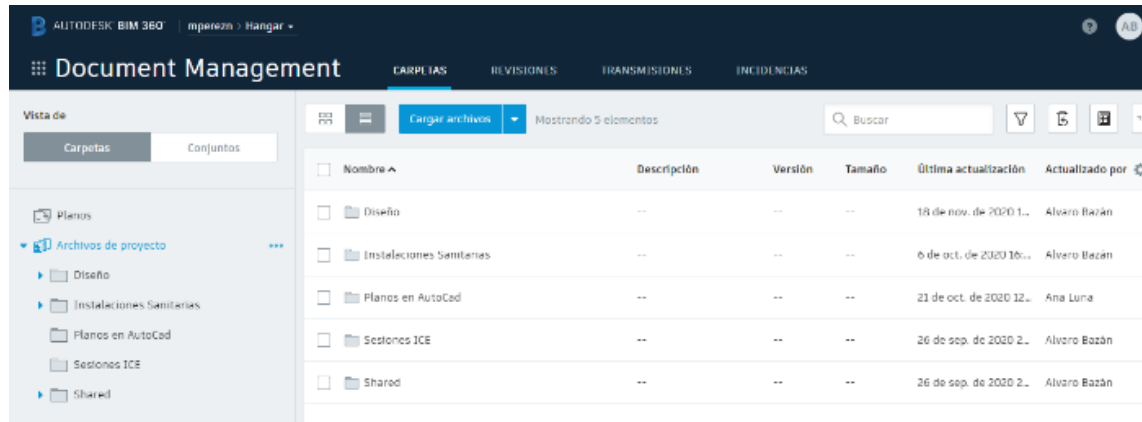
**Structures  
Laboratory**

**Environmental  
Engineering  
Laboratory**

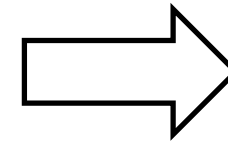
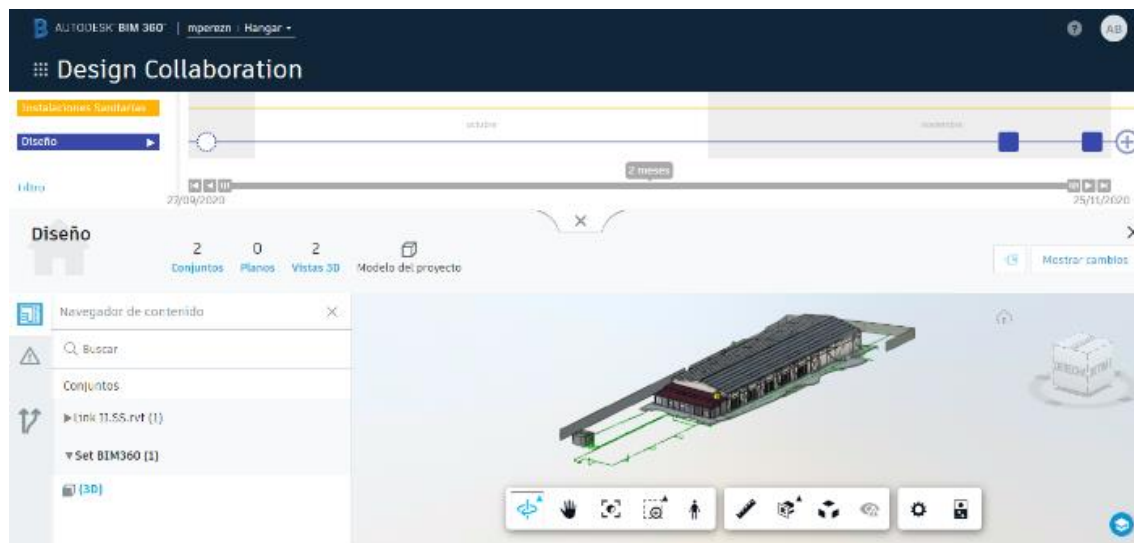
**Pavement  
Laboratory**

# Results of BIM metrics and controllable factors

Pictures that describe the implementation



From session 40 onwards, a CDE (BIM 360) was implemented in the project to increase collaboration between stakeholders and facilitate the transversality of information.

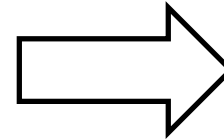


Integrating the models (Architecture, Structures, Sanitary, and Electricity) is handled with the platform, which facilitates the exchange and integration of information.

# Results of BIM metrics and controllable factors

## Tables to Obtain the Current LOD

Specialty	Area	Impact	Desired LOD	Actual LOD	Completed
Laboratory	SE2H Equipment	Very High	500	300	No
	Equipment Lab.Ing.Amb.	Very High	500	100	No
	Structural Lab Equipment	Very High	500	350	No
	Pav. Lab Equipment	Very High	500	100	No
	Lab Equipment Mat.	Medium	300	100	No
	Lab Equipment Geotec.	Medium	300	100	No
Specialty	Area	Impact	Desired LOD	Actual LOD	Completed
Architecture	Lab.CIC Furniture	High	350	300	No
	Furniture of Labs. Mat and Geo	Medium	300	300	Yes
	Offices	Very Light	100	300	Yes
Specialty	Area	Impact	Desired LOD	Actual LOD	Completed
Structures	Structure Lab. Portico	Very High	400	200	No
	Foundation Porter Lab Structures	Very High	400	200	No
	Partitioning Lab. Environmental and Pav	Very High	400	200	No
	Steel Structure	High	350	350	Yes
	Portico Foundations	High	350	200	No
	Bridge Crane	High	300	200	No
	Office Structure	Mild	200	200	Yes
	Office Foundations	Very Light	100	0	No
Specialty	Area	Impact	Desired LOD	Actual LOD	Completed
Sanitary Systems	Cold Water	Very High	350	350	Yes
	Drainage	Very High	350	350	Yes
	Extractor hood	Very High	350	0	No
	ICA	High	300	350	Yes
	Water for Rain	Medium	200	0	No
Specialty	Area	Impact	Desired LOD	Actual LOD	Completed
Electromechanical Installations	Offices	Medium	200	100	No
	Lighting Labs	Very High	350	200	No
	Data Connection	Very High	350	0	No
	Power Socket	Very High	350	200	No
	Boards	Very High	350	200	No
	Earth	Very High	350	0	No

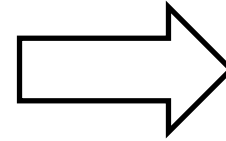
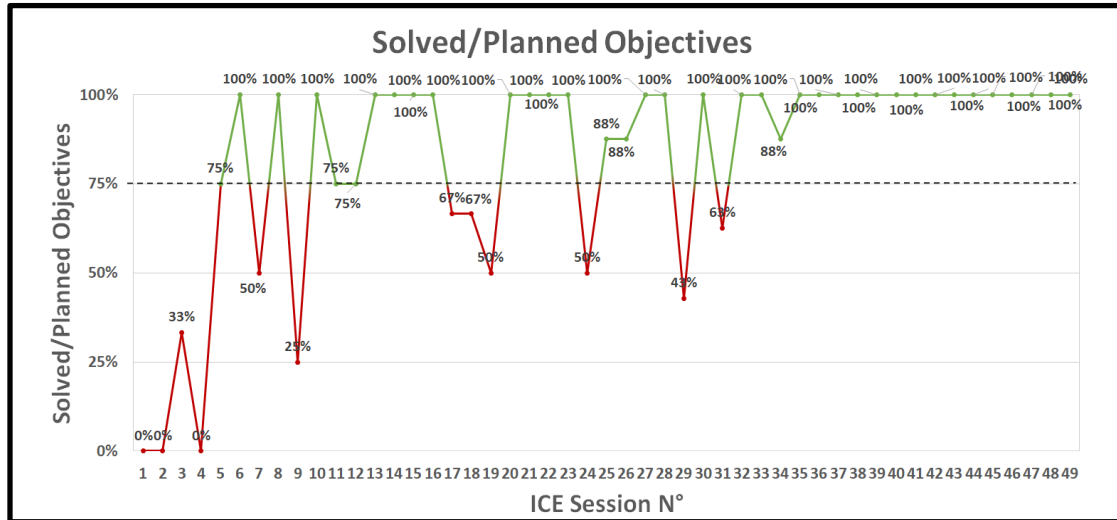


The groups of elements that are in each area or system are separated and identified.

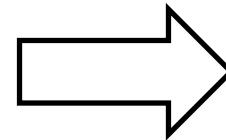
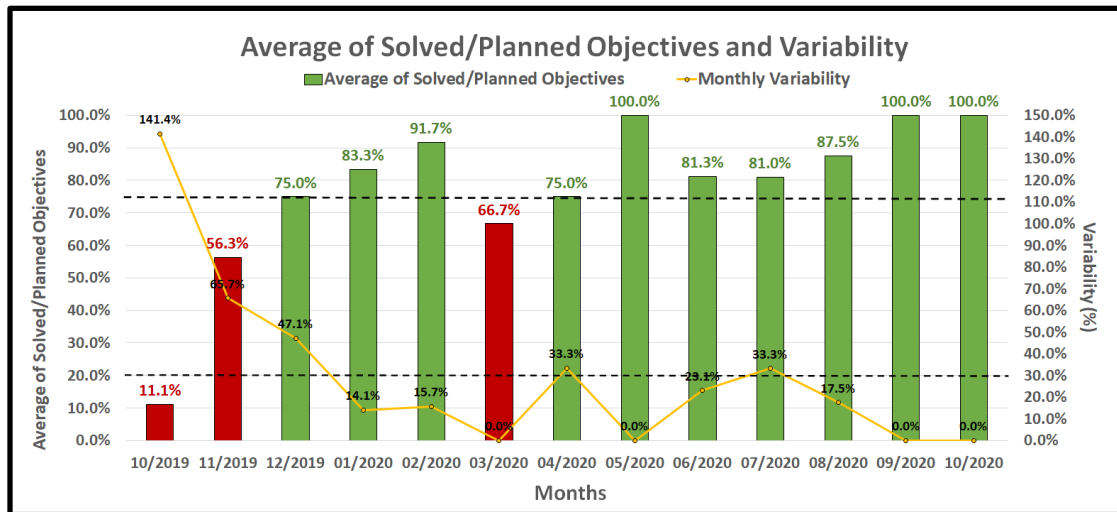
Then, a weighted value is calculated for the elements and rounded to the nearest LOD.

This should be included in a BIM Execution Plan (BEP).

# Results of PPM metrics and controllable factors



**We have improved in the resolution of the planned objectives. The use of a more detailed agenda has helped. We are considering increasing the goal to a higher value.**

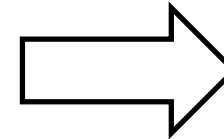
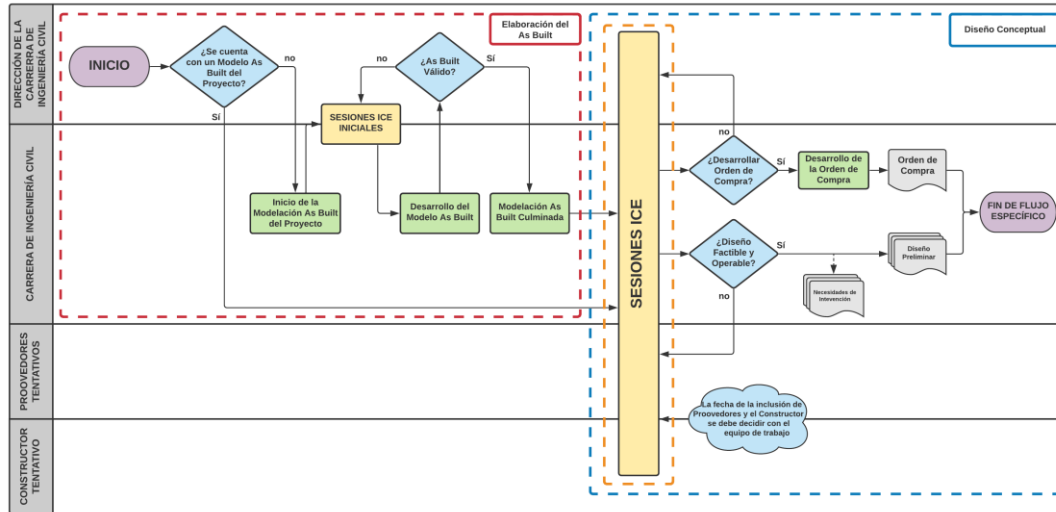


**In the last two months, we have solved 100% of the planned objectives, resulting in 0% variability. These results have motivated the team a lot.**

# Results of PPM metrics and controllable factors

Pictures that describe the implementation

PPM

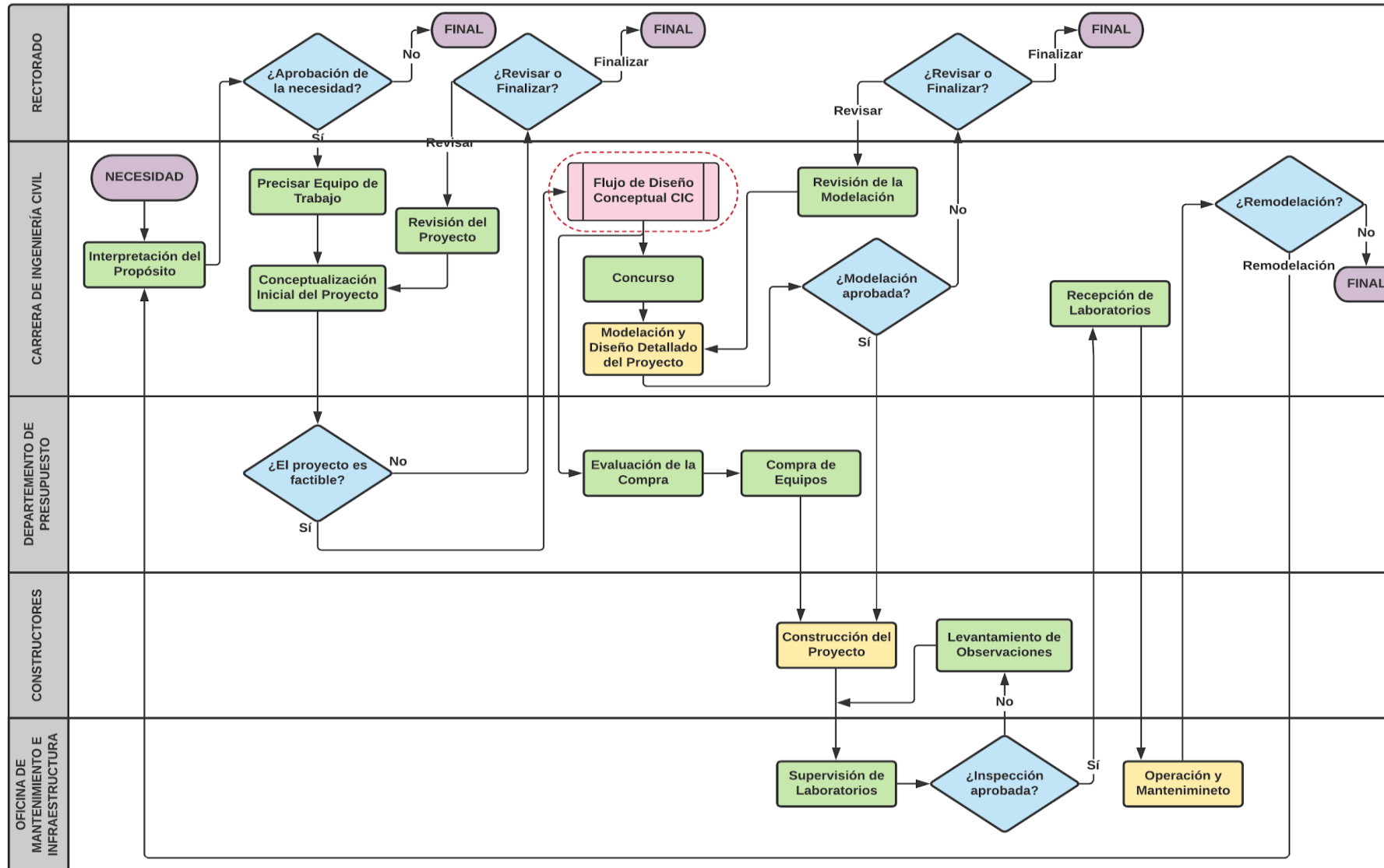


Conceptual Design Process



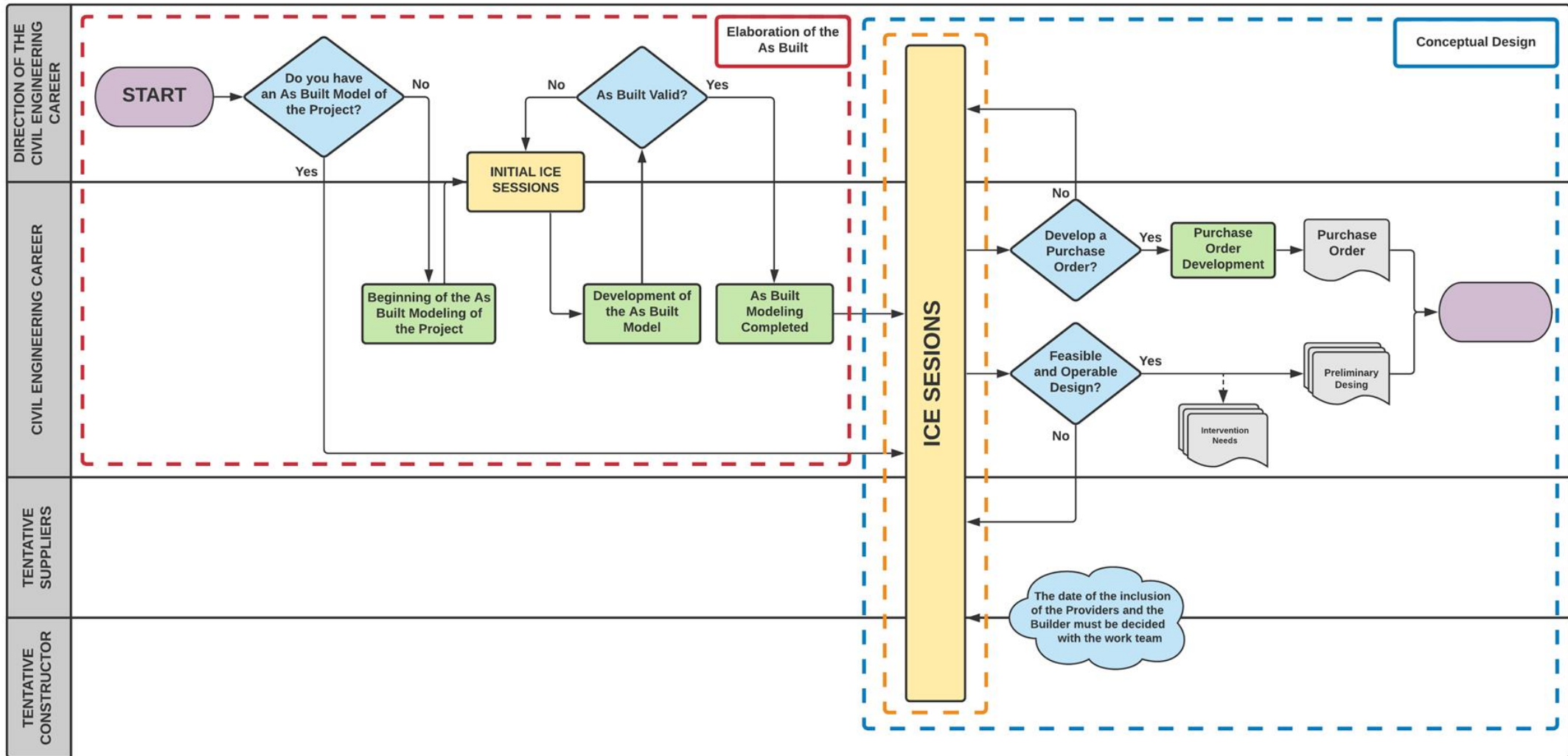
# Final process based in VDC with metrics

## Project Macro-Flow



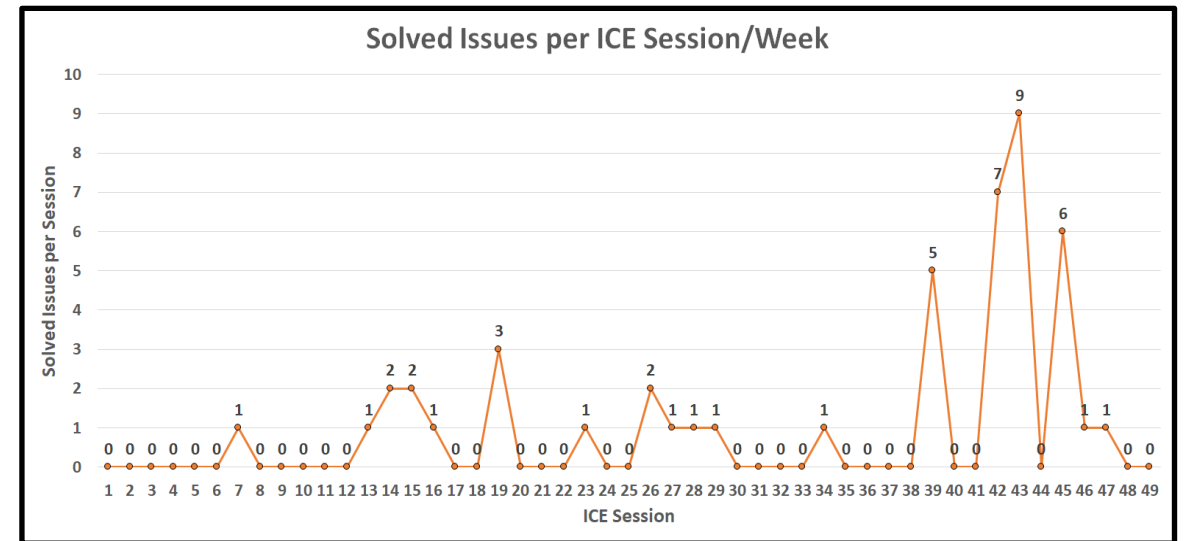
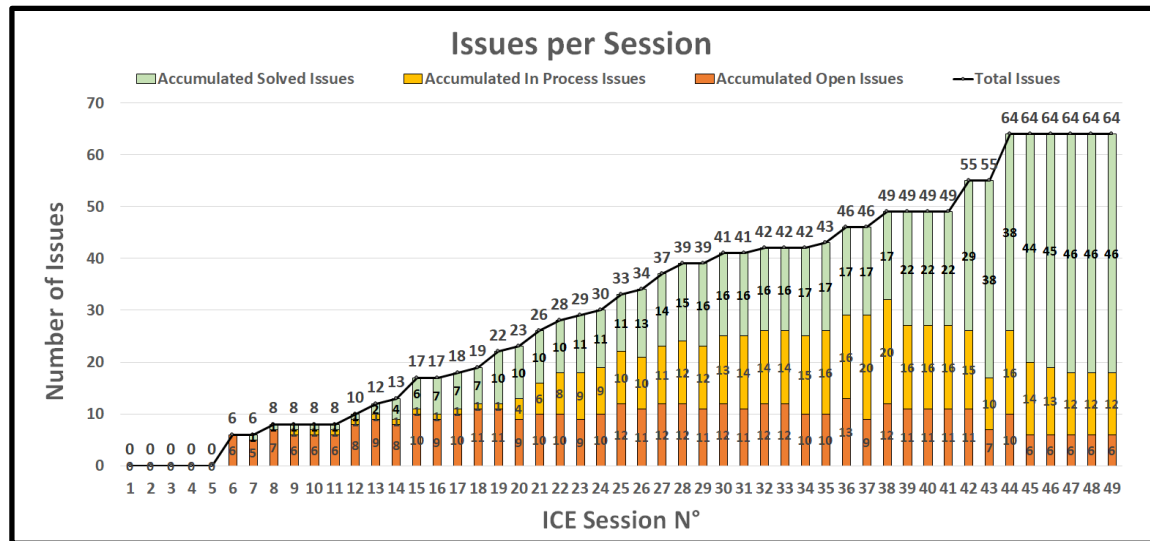
# Final process based in VDC with metrics

## Conceptual Design Flow



# Conclusions and Reflections

- **Percentage of issues solved**
  - This production metric reflected our tracking and problem-solving capacity over time. It supported tracking all the issues that had to be solved before delivering the final conceptual design.
  - Besides, this metric pointed out the need to improve our performance in solving issues, which then became a major critical factor to be concerned about in our ICE sessions.
- **The main project objective is based on delivering dates.**
  - Although everybody was focused on finishing their weekly tasks, the deadline was always reminded and helped the team stay aligned with the project objective.

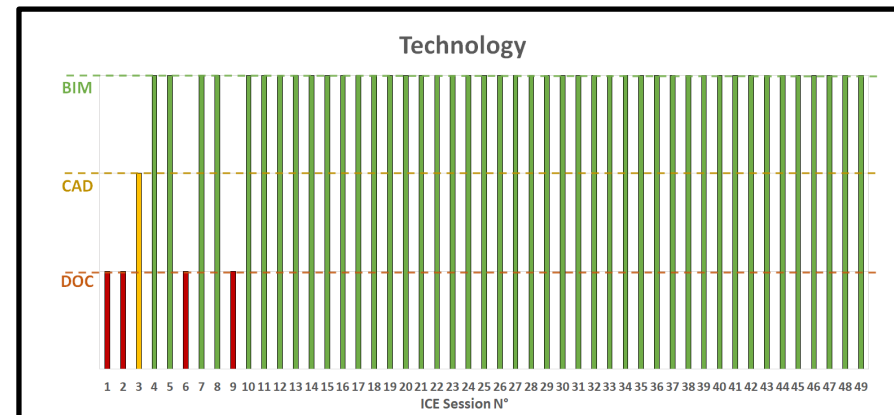
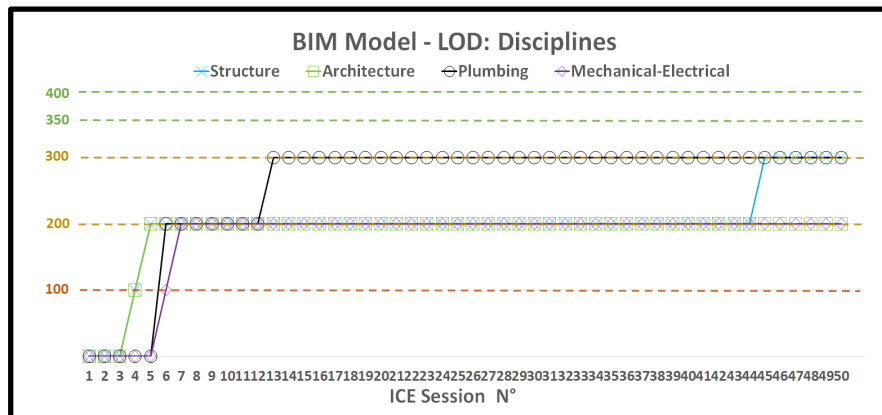


# Conclusions and Reflections

- **Percentage of issues solved**
  - Solving all the pending issues is a requirement to reach the final design without problems.
- **BIM Level of Development (LOD)**
  - We haven't reached the BIM target of a 350 LOD model. After analyzing it, we realized that we defined a higher LOD target for a conceptual design stage, which should be lowered.

## General Comments

- From all the production metrics used, the only one we have recently discussed to stop tracking is the 'Level of Technology used in ICE Sessions' metric.
- BIM has become a crucial support in the development of ICE Sessions. We have worked on and always discussed BIM in the last 30 ICE sessions.



# Conclusions and Reflections

## Biggest forces for and against your VDC implementation

Force for	Impact of positive force	What enabled the positive force?
BIM used in ICE Sessions	More detailed information and visualization of the laboratory as built.	Increase the number of proposals for the laboratories' distribution.
Virtual and remote work	More commitment and less time waste.	Reduce the variability in some metrics, such as ICE sessions duration, assistance or starting time.
Level of influence	Promoting and motivating the team to start applying VDC.	The usual efforts putted into VDC influence were transferred mainly into how to start applying it.
Force against (Obstacle)	Impact of Obstacle	Cost to the Project or Company
Lack of training in VDC	In the beginning, the team was not totally engaged with the VDC tools and methodology.	It took some time until the ICE sessions reached a certain level of efficiency.
Definition of a detailed process	A certain level/rate of production was not specified.	The lack of metrics on processes like BIM production.

# Conclusions and Reflections

## Personal Learning Points

**BIM in ICE Sessions:** We have learned and optimized the use of BIM during the ICE Sessions over time. Some of the main benefits are a more integrated virtual team to the project and the design approach.

**Virtual and remote work:** The team and the ICE Sessions have become 100% virtual, leading to a remarkable reduction in duration and starting time variability. Also, the team feels more comfortable with the work environment.

**Track and management of issues:** As a learning point, we understood that this metric had to be implemented and tracked from the beginning. After some ICE sessions, we realized that we were more concentrated on reporting weekly than doing a precise follow-up of issue solving.

**ICE Sessions management:** ICE Sessions management is one of the critical factors practitioners should be concerned about. ICE sessions must have clear goals, with participants well-informed and prepared to work on solving and taking decisions during the ICE session development.

**Team alignment with BIM:** The team reached a high level of knowledge and alignment with BIM. This was achieved by using online viewers to facilitate accessibility and visualization of the BIM model, present in a CDE.

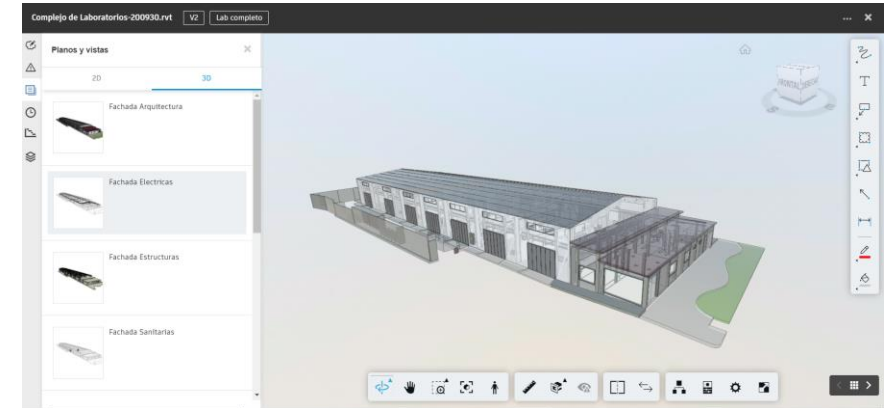
**In-house project development:** It seems more accessible to implement the VDC framework in in-house projects, where the participants are more willing to change and use new methods and tools.

# Conclusions and Reflections

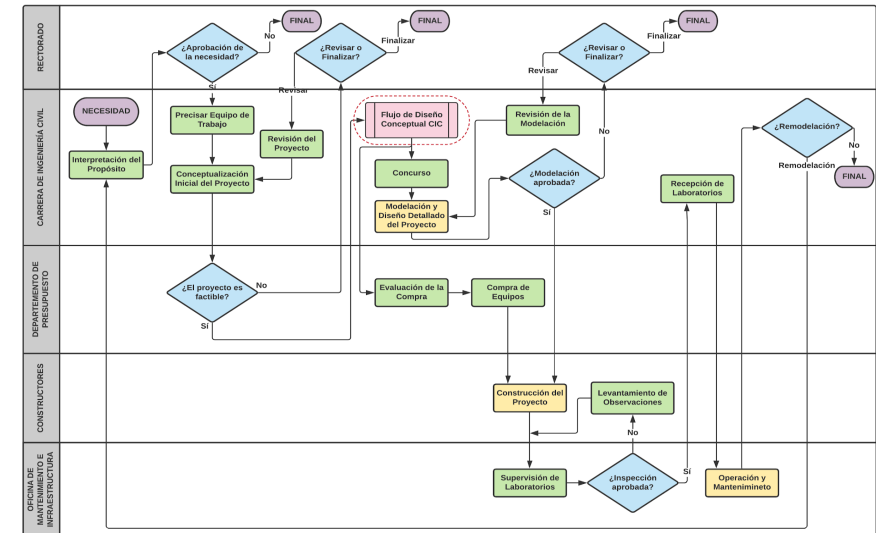
## Changes to how you manage projects

- Organizational changes that did happen:
  - BIM Optimization (CDE and displays).
  - Partial handling of PPM.
  - Inclusion of the suppliers in the conceptual design process.
- Organizational changes that should happen (or should have happened):
  - Collaborative management focused on solving issues.
  - Establish and implement a CDE from the start.
  - Management/use of BIM by the entire team.
  - PPM optimization.
  - Establish a procedure based on periodic goals reevaluation and updating, based on results obtained throughout the VDC implementation.

### CDE – BIM 360



### Proposed work-flow



# Recommendations for other projects

- Working on similar projects
  - 1. Establish a PPM production system**
    - Implement the production system in a design process.
    - The capacity, inventory, and time must be carefully analyzed and assigned.
  - 2. Elaborate a BIM Execution Plan (BEP) with production metrics and controllable factors.**
    - It's common to use BIM and start modeling every discipline at a high LOD.
    - A detailed BEP focused on accomplishing the BIM production metrics and controllable factors is needed.
- To your manager
  - 1. Invest in tools and trained staff**
    - VDC tools and requirements change from project to project.
    - It's recommended to evaluate and invest in tools that benefit the project.
  - 2. Work on improving the ICE Sessions management**
    - ICE Sessions management is key in integrating and connecting the participants to solve issues and make decisions collaboratively.
    - It's crucial that each ICE Session is well organized to reach the defined goals.



# Recommendations for other projects

- To your company
  1. **Establish an organizational culture based on collaborative management with VDC.**
    - We recommend motivating and promoting the adoption of VDC methodology in the whole company.
  2. **Promote a continuous improvement culture by comparing common metrics from project to project.**
    - Not only from project to project but in the same VDC application by establishing periodic metric reevaluations. One of the key success factors is to constantly question our VDC progress and methods for a better outcome, even if it seems we are already doing well.

# Key reactions to VDC from colleagues, clients, partners

*“From my perspective, it is (VDC) a very effective and collaborative methodology that has allowed us to optimize time and schedule. Overall, VDC let us visualize critical points in our project that probably wouldn’t have been noticed with other methodologies. I can safely say that I will implement this in future projects where I get involved.”*

– **Ricardo Madrid, Pavements’ Laboratory chief**

*“The Civil Engineering Laboratories’ VDC application has allowed us to analyze some important aspects of the project. Firstly, the spatial distribution was optimized, considering the already existing infrastructure and the limited area available. On the other hand, we’ve achieved the adequate location and layout of 6 new laboratories in a common area. Finally, the connection between BIM tools and VDC with ICE has led us to take quick decisions, fix errors and consider new common services.”*

– **George Power, Sanitary, Hydraulic, and Hydrology Laboratory chief**

# Key reactions to VDC from colleagues, clients, partners

*“VDC method seems very comfortable from sight, as well as in practice. Innovation, creativity, and ease are some of today’s essential characteristics applied to this technology, which generates multi-disciplinary work between parties. The VDC implementation for this laboratory’s design is unique because none of the other laboratories at the University of Lima are applying this method that fits into the Civil Engineering Department proposal.”*

– **Israel Montoya, Materials’ Laboratory chief**

*“As a Costs chief at the Civil Engineering Laboratories, I usually used Excel to generate the lab test expenses and others. It has its limitations. Therefore, VDC collaborative work allows to effectuate and evaluate diverse cost alternatives, considering the design changes in infrastructure, supplies, and constant variation in the number and duration of tests. Overall, the framework facilitates the lab management and its capability to compete in the service market.”*

– **Juan Carlos Yácono, Laboratory’s Costs chief**

# Final Conclusion

- We developed Virtual ICE sessions every week, in which all laboratory managers participated and invited personnel to coordinate and resolve issues. Also, we develop and manage a high-detail BIM model with all the specialties and laboratories, containing all the product information to be built within the on-cloud platform BIM 360. Finally, we applied a PPM production system focused on solving issues for each session, reaching the desired conceptual design according to the client's needs.
- We have benefited from working on virtual ICE sessions, reducing the meeting time to a third compared to face-to-face sessions. In addition, decision-makers' attendance increased by approximately 10%, and variability was reduced by approximately half. In addition, the early involvement of the equipment suppliers allowed the inclusion of details that would facilitate the construction, operation, and maintenance of the equipment to be installed. For example, in the laboratory of structures, it was possible to identify 12 new key items for the laboratory and include them within the conceptual design. Moreover, using a task management platform increased 7 times the speed of solving pending issues.
- Finally, the conceptual design was achieved by solving 100% of the issues. Likewise, the equipment purchase orders were successfully requested one month before the deadline. The equipment request and laboratory conceptual design fulfilled the installation, operation, and maintenance requirements.

# Thank you!

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