BIM Application in Construction Management

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BIM METHODOLOGY
FERNAN VARGAS RENZI
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BIM, Construction Management, BIM Application, BIM 360, Synchro Software, KPIs

Executive Summary
Building Information Modelling (BIM) does “work” in the field. There is plenty of room for improvement and smoother interoperability between field systems and tools in the construction management ambit, but a valuable opportunity is overlooked by firms that omit the use of today’s technologies and leverage on the construction site. The model coordination plan and the conventional BIM approach continue playing a critical role in the BIM design environment; but the author attempts to produce a BIM methodology that is both practicable and feasible in the construction management discipline. The dissertation paper focuses on the implementation of two highly-recognized software of BIM 360 Field and Synchro Pro with their respective tablet applications. The author presents workflows for tasks executed on-site and then demonstrates how the methodology successfully meets the nature of the activities by means of either software. The author confirms that BIM products can be configured to pursue activities that are proper of a Construction Management firm even when both software were originally designed to serve General Contractors. The methodologies are invented to go far-and beyond the prime objective, thus enhancing the overall process. Key performance indicators are presented to corroborate the viability of the application of the author’s methodologies.
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1. Introduction

1.1 Main Objective

The main objective of the dissertation paper is to prove that market-available BIM software can be successfully implemented to achieve activities and functions proper of the Construction Management ambit, through the methodologies presented by the author. BIM inventions and technological advancements have revolved around the idea of optimizing the design phase of the construction lifecycle, but less in activities relating to control and management of the construction phase. The document aims to ascertain a methodology that bridges the gap between the software and tasks purely associated to Construction Management within the Lean Construction philosophy.

The software selected to validate the theory are BIM 360 Field from Autodesk and Synchro Pro from Synchro Software with their respective tablet applications. The scope of BIM 360 Field comprises monitoring, controlling and digitizing of tasks performed on-site while Synchro Pro will target real-time management of the activities executed on the field in relation to the project schedule. The dissertation paper uses the Foc Cisell Station of the L9 Project of the Barcelona Metro System to experiment and extract the presented results.

1.2 Secondary Objectives

- Substantiate the implementation of the methodologies with calculations derived from key performance indicators established before commencement of the applications. These KPIs corroborate with the author’s declarations by demonstrating the optimization of processes and the improvement in their performance, as well as a feasibility study that exhibits the earned value instigated from the implementation.
- Incentive the industry to move into these less-traditional methodologies that eliminate waste and improve the overall quality of the project. The author attempts to minimize the irrational fears that Building Information Modelling (BIM) has only been developed to accomplish specific ambitions and is not economically viable for small and medium-sized enterprises.

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1.3 Background

1.3.1 Foc Cisell Station and L9 Project
The dissertation focuses on the station Foc Cisell of the project L9T2 of the Barcelona Metro System. This segment of the Line 9 (L9) metro branch structure is known to the public as the Line 10 South (L10 South) which stems from Gornal to the Poligon Pratenc.

L9 is a line of the Barcelona Metro network that is currently under construction and will serve the cities of El Prat de Llobregat, L’Hospitalet de Llobregat, Badalona, Santa Coloma de Gramenet and Barcelona. The project was bid by allotting L9 in 4 sections of which section 1 and 4 are already functioning, section 2 is under construction and section 3 is still searching for its funding. The first section serves the El Prat Airport and Zona Universitaria (L9 South). The second section connects Zona Universitaria with Poligon Pratenc (L10 South). The third section will join Zona Universitaria with La Sagrera. The importance of this third section births from the fact that it will unify the entire L9 and allow it to become the longest automatic train operation (i.e. driverless vehicle) metro line in Europe. The fourth section was appointed to be the segment that travels from La Sagrera to Can Zam/Gorg (L9 North). Figure 1-1 below depicts the L9 project separated by its distinct sections mentioned previously and highlights how the third section will serve as the linkage between the other sections. The image was chosen so that the reader can comprehend the various sections of the L9 line, however the individual stations may not be appreciated correctly since the image is huge and was reduced.

Figure 1-1: Sections of the L9 Project (Section 1 first from left to right and Section 4 the last) [1]
L9 of the Barcelona Metro Network presently has 27 stations in operation: 12 in the northern segments and 15 in the southern segments. Once the 4 sections are finished, the L9 will stand with 47.8 km in length of which 43.71 km are underground, becoming the longest underground line in Europe. The ambitious project will not only provide a viable metro service to some neighborhoods that are currently without the service (Bon Pastor, Llefià, la Salut, Singuerlín, Pedralbes and Zona Franca) but also link some key city locations (El Prat Airport, Zona Franca, la Fira, Port of Barcelona Expansion, Ciutat de la Justícia, el Parc Güell and Camp Nou Stadium) [1]. Figure 1-2 shows the magnitude of the L9 project and its trajectory which permits the reader to comprehend the importance of such a line for the city and its suburbs.

The L9T2 (L10 South) roots from the necessity and demand to integrate the Zona Franca region to the rest of city. Since the L9T1 is already functioning, the stations from Gornal to Zona Universitaria are already up and running. Tram 2 requires the construction of the segment of Gornal to Poligon Pratenc which varies from the rest of the L9 given that it also accounts for a portion that was built as a viaduct. Figure 1-3 illustrates the estimated inauguration dates of four of the main stations for the L10 South line (Provençana, Ildelfons Cerdà, Foneria and Foc Cisell) which stresses how the project is at a culminating and critical stage.

Figure 1-2: L9 of the Barcelona Metro Network [2]
Foc Cisell is one of the stations of the L9T2 project and will be briefly explained since the entirety of this thesis paper is founded on this metro station. Foc Cisell is located between the stations Foneria and Motors of the L10 South, in the Sants-Montjuic District of Barcelona. The station has two main entry ways, both stemming from the Passeig de la Zona Franca, but one serves the Carrer de Foc while the other Carrer de Cisell. Figure 1-4 is an aerial view of the location of Foc Cisell in comparison with the entire city of Barcelona. The station is a deep underground structure that follows the geometry of a water well. The station intersects the tunnel in such a way that the slab between the upper and lower platforms is lined up with the center of the tunnel. The station has six stories, the maximum height distance being between the street level and the inferior platform at 32.35 meters. The station’s main lobby is 8.44 meters below street level and is accessed by either of the two entrances. To attain the height differential between the lobby and the platforms, 4 or 5 (depending if upper or lower platform) mechanical escalators are used to reach the tunnel. The upper platform runs with the natural slope of the city, mountain to sea. This upper platform will carry the passengers in the sense of Foneria to Motors. The lower platform will course in the opposite sense, cruising from Motors to Foneria. [4]
Foc Cisell is a unique station in many ways, from its incredible depth below the surface to even its architectural beauty. Foc Cisell’s concept is inspired by the station Fira 2 (part of the L9T1 or L9 South) and was conceived by the same architect, Toyo Ito. Toyo Ito’s vision of the station is specially conveyed by the lighting of the spaces where he chose to utilize light fixtures and materials that are environmentally friendly and gracious to the eye. The concept is best described by the following:

- **Station as a historical museum of Fira**
  - The station will have photographs that capture the essence and history of Fira and its long-standing connection with the city. The images will be carved in the ceramic pieces that decorate the station’s walls.

- **Station as a welcoming gate to Fira**
  - The design of the station will use patterns and materials that resemble those of Fira. People will recognize these similarities and infer that they are close to Fira and whatever event beholds them inside.

- **Theme of the station**

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**Figure 1-4: View of Barcelona when the north direction is pointing straight up**[5]
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Figure 1-5 is presented to give the readers a sense of how Foc Cisell is located with respect to Fira. The design of Foc Cisell is heavily dependent on its location so this image tells a story of the reasoning behind Toyo Ito’s inspiring scheme.

Figure 1-5: Birds-eye view of Foc Cisell and proximity to Fira Complex [5]

1.3.2 3D Model Context
A 3D BIM model is a digital representation of the physical and functional properties of a structure or installation. Planning from the early stages of the project is a key stipulation if a project wants to successfully implement BIM. The generation of a 3D BIM model consists in the upbringing of a structure in a way that all the elements that constitute it have integrated one another. This integration of elements enables detecting clashes and interferences for any structural, architectural and MEP component. The 3D model is more than a bunch of its pieces, it is a compilation of integrated elements that coordinate to form a structure. The 3D model of Foc Cisell was created by utilizing the following software: Autodesk Revit MEP 2016, Autodesk InfraWorks 2016, Autodesk Civil 3D 2016, Bentley AECosim Building Designer V8i, Bentley InRoads V8i. However, before the 3D model is shaped, the entities involved in the project must come together to plan and convey their aims.

A thorough BIM Execution Plan (BEP) will guarantee that all the entities involved are informed and cognizant of the opportunities and responsibilities they partake in the project. The BEP defines the objectives of the implementation, the level of development or detail required, the scope of the application, the way it will be executed, the software utilized, how the project will be managed, amongst others. Once all of parties involved have reached an agreement, the BEP will serve as guidelines to manage the project through its various stages. Figure 1-6 is a graphical representation of the 4 steps deemed necessary by textbooks and literature in order to construct a suitable BIM Execution Plan:
1. Identify and define the goals of BIM during the planning, design, construction and operation and maintenance phases.
2. Design a processes map that will determine which tasks are within the scope of the BIM implementation.
3. Develop the information content, the level of development of the model and the information exchanges.
4. Define the assets and infrastructure required to support the application of the BEP.

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**BIM Project Execution Planning Procedure**

- **Identify BIM Goals and Uses**: Define project and team value through the identification of BIM Goals and Uses.
- **Design BIM Project Execution Process**: Develop a process which includes tasks supported by BIM along with information exchanges.
- **Develop Information Exchanges**: Develop the information content, level of detail and responsible party for each exchange.
- **Define Supporting Infrastructure for BIM Implementation**: Define the project infrastructure required to support the developed BIM process.

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The primary goal of the BEP is to have a BIM model for the execution of the architecture and MEP of the Foc Cisell station. The modelling and level of development will be focused on the following:

1. Geometrical representation of the tunnel and station structure.
2. Integration of the station and tunnel with its environment.
3. Depiction of some interior partitions of the station and tunnel.
4. Representation of the tiling and ceramics of the interior façade, mechanical escalators, platforms and lower lobby.
5. 3D modelling of the MEP (especially the ventilation system and fire suppression system).

The geometrical information for Foc Cisell has been divided in four groups according to the discipline which meant that the project would be comprised of four 3D models that would later be merged into a Coordinated Model. The elements chosen to be modelled based on their importance to the client are listed below:

- **Environment**
  - The environment model encompasses urban development information directly linked to the construction of Foc Cisell station. This model will also contain topography data and general information regarding the structures around the

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station. The level of development for this model was set to be LOD 300 for the elements defined as significant in the BEP. For this model, the elements that were defined as significant are: Barcelona railways, stairways and PMR elevators.

- **Structural**
  - The structural model will serve as the carcass in which all of the elements are centered through. The structural systems included in the model include the access ramps, emergency stairways, the tunnel with its platforms, the slabs, some interior walls and the main retaining walls. The level of development for this model was set to be LOD 300 for the elements defined as significant in the BEP. For this model, the elements that were defined as significant are: footings, braces, slabs, slurry walls, columns, supports, escalators, floors, RC beams, trusses, beams and joists.

- **Architectural**
  - The architectural model includes the systems of the tiling and ceramics of the interior façade, mechanical escalators, platforms and lower lobby. Interior and exterior carpentry, pavements, elevators, bathroom fixtures, partitions and metalwork are not part of the scope of the project and hence were not included. The level of development for this model was set to be LOD 300 for the elements defined as significant in the BEP. For this model, the elements that were defined as significant are: partition walls, ceiling fixtures, paving, stairways and ceramic tiling.

- **MEP**
  - The Mechanical, Electrical and Plumbing model incorporates the fire suppression system and the ventilation system for the station. The model excludes all the sanitary equipment, plumbing, electrical boxes, command operation boxes and electrical cable trays. The level of development for this model was set to be LOD 300 for the elements defined as significant in the BEP. For this model, the elements that were defined as significant are: interior units, ventilation fans, fan silencers, fire dampers, fire regulators, impulsion system, return system, ventilation system, primary air system, air grilles, deposits, pressurized system, valves, devices, pipelines PCI, stopcocks, fire sprinklers, firefighting system, fire extinguishers, fire control units and smoke detectors.

The merged 3D model is displayed in Figure 1-7. The sections that deal with the specific software will go into more detail and present other views of the model. This Figure was obtained from Navisworsk Manage 2017.
Figure 1-7: 3D Model as viewed in Navisworks Manage (Author)
2. Literature Review

2.1 BIM in Industry and Case Studies

The application of BIM software in construction has been strongly linked and developed in the design phase of a construction project. Many of the bigger technology companies have invested on programs that bring together 3D models with analysis, budgeting and planning aspects. These software range from Autodesk’s Navisworks to RIB Spain’s Presto and even locally with ITeC’s TCQ version 5.3. The purpose of mentioning such software is to emphasize how the entire industry is shifting and following this BIM phenomena, from macro companies trickling down to even some regional ones.

The current knowledge on the topic of this specific dissertation is difficult to grasp since it is a novelty and the information being generated within companies involving these developments around the globe convey certain discretion. Gaining an advantage on the competition with technology like this may prove to mean whether a bid is won or lost. To perform the research required to write a thesis paper on the matter, the software companies themselves had to be studied since they proudly display their successful case studies. Scholarly articles were also useful to understand the vision of some of the minds behind this revolution and to gain some insight on the means of this technology.

Most research has been focused on how a successful BIM implementation can benefit a project by either reducing costs and/or meeting the project schedule. The case studies presented below follow a typical flow in which a company sets some KPIs (Key Performance Indicators) to comprehend whether the investment is worth it in the short and long runs. It is key that all the stories being told are either from construction companies or subcontractors, none taken from a project management perspective but from a “how it is being built” one. This differentiation must be understood to profit from the reading of the dissertation; BIM tools that are applied during the design and construction phases do exist, but it is the application of these on a more stringent basis of tasks related to construction project management that is unexplored territory.

Case Study 1: Beca Group and BIM 360 Field

Beca Engineering was commissioned as the project manager and lead consultant for the Building Services and Seismic Structural design for a new Cathlab Facility at Tauranga Hospital. The building was constructed in 2011 and had several stories that were currently empty, waiting to be filled in. The client asked Beca that as a requisite at the conclusion of the project it was mandatory to have a schedule of critical maintainable assets. Beca Group used BIM 360 Field to capture data during the construction stage. They understood that BIM 360 Field could be used a means to an end that allowed the required asset list to be incorporated into the hospital’s existing asset management solution. [7]

This case study is useful because it demonstrates how the bigger fish in the market understand that this industry movement towards BIM is inevitable, it is just a matter of who is in and who is not. Beca Group decided to utilize BIM 360 Field as a tool that allows them to carry on all of the information generated during the construction to the operations and maintenance phase. BIM 360 Field is very capable of attaching all kinds of documentation to the equipment and asset lists such as PDF documents, images, checklists, issues specific to the asset while logging all of the users that participated with the documentation (uploading, deleting, mark-ups, creation of issues and tasks, along with others). Beca Group barely scratched the surface of the potentials that BIM 360 Field has because they were given a specific command on what the
client expected of them. Beca Group concluded that deploying BIM 360 tools reduced drastically the time it took for them to capture, create and distribute information.

Case Study 2: Consigli Construction Co. and BIM 360 Field

Framingham State University needed to accommodate an increasing enrollment, so they decided to build North Hall. Three construction goals were set: open on time, on budget, and to minimize the disruption on campus life during its construction. Framingham turned to Consigli Construction Co., Inc. to deliver the project using CM at risk mode. The importance of staying on schedule was critical since the university had already accepted a lot of students that would be placed in this new edifice. Consigli used BIM 360 Field to review project progress and generate punch lists to highlight outstanding items. \[8\] This case study illustrates the way construction companies are really using BIM 360 Field. Autodesk proudly displays the case study but not because of the way in which BIM 360 Field is being used but because the project also involved Autodesk Revit, Navisworks and BIM 360 Glue. Companies tend to say they are full users of BIM 360 Field but are not heightening its purpose. BIM 360 Field is a software that enables for so much more than the creation of punch lists. These companies are using the software to aid them in whichever way tailors best to their need, but many more features can be set for the automation of construction management on a day-to-day basis. Consigli Construction Co., Inc. fathomed that this potent program can also convey data into the commissioning phase as all the information about the equipment, such as maintenance schedules, manuals, and warranties, are linked and available after finalizing the construction.

**Figure 2-1:** 3D rendering of the North Hall[8]
Case Study 3: Max Bogl Group and BIM 360 Field

Max Bogl Group decided to test the BIM 360 Field software in shopping mall that the firm would own and operate. The firm was looking to improve two crucial but inefficient processes: QA/QC and safety inspections in this first pilot. Max Bogl Group recognized that these two processes relied heavily on paper-based methodologies and believed that the BIM 360 Field application would cut into the time it took documenting and communicating inspection issues. The pilot was a success and the company was able to dig and explore some of the most specific characteristics of the software like creating QR codes within BIM 360 Field that would take the user straight into a specific 3D object and display all the data within it. [9]

This case study is pertinent because is the only one found on the European continent. Max Bogl Group is the largest privately-owned construction company and is determined to stay ahead of the curve. The pilot project undertaken by this construction firm demonstrates more of the capabilities of the software as the case study brings forth details of the methodology applied by the firm. It is certainly impressive to see that this pilot project involved subcontractors and the communication channels that could be created using the software. Many of the success case studies displayed on the Autodesk website reveal stories of pilot projects held internally since all of the output and lessons learned are valuable assets going forward. Max Bogl Group concluded that by managing its QA/QC processes in BIM 360 Field, they can better maintain the pace of construction.

Figure 2-2: iPad being used on-site by the Max Bogl Group [9]
2.1.1 Interview Professor Ignacio Valero about the current application of BIM in construction

The author decided to conduct an interview to comprehend the current situation concerning the application of BIM in diverse ambits and sectors of the civil engineering industry. The full length of the interview is presented in Annex 1 in its original version of Spanish but a summary of the main strides hit by Mr. Valero will be presented in the following paragraph.

The author was keen to see if his approach on the application of BIM products and methodologies on specific tasks and activities relating to Construction Management was presently being employed throughout the region. Ignacio Valero has travelled around the globe and his vision represents much more than the local view. Mr. Valero presents his arguments on why Spain is lagging a bit behind other industrialized nations and why he believes this is hindering the ability to apply newer technologies such as BIM. His vision is aimed at the fact that the curriculum being offered by the best schools in the nation are focused on the mathematics, physics and other subjects while omitting emerging technologies. He believes that it is just a matter of time before these technologies take over the industry and people will be forced to adapt them regardless of their affection for them.

Ignacio Valero states that his conviction lie heavily on implementing the software more on the planning before taking it on-site and this is because he believes that most inefficiencies and mistakes underlie on the planning of the project and how poorly it is handled. The author asks Mr. Valero if he has ever heard of a Construction Management firm applying BIM software for the sole purpose of controlling a project and monitoring its day-to-day activities for which he replies that he has seen how bigger engineering firms are investing on these developing technologies in the pursuit of ravishing the benefits these may produce but has yet to see them applied on a big scale due to the complications involved and the extreme differences between two construction project.
2.2 Theory and Key Concepts

2.2.1 Lean Construction

Lean construction serves as a management system, philosophy and attitude that attempts to permeate the principles of manufacturing that generate value and eliminate waste. Throughout the various phases of the construction cycle. Lean construction is a “way to design production systems to minimize waste of materials, time, and effort in order to generate the maximum possible amount of value”.\[10\] Lean Construction must be understood and studied before venturing into everything that entitles BIM since it stands as the seed that enabled BIM to gain its footing and sprout into the phenomenon known today.

The core of lean methodology perches in the observation that there are two aspects in all production systems: conversions and flows.\[11\] While all activities expend cost and consume time, only conversion activities add value to the material or piece of information being transformed into a product. Whereas most people believe that the main goal is to target these conversion activities, the improvement of non-value flow activities, which bind the value adding activities together, should also be principal focus. Traditional managerial practices stress the importance of controlling and managing these conversion activities, but many of the non-value adding activities (inspections, moving, searching) have been left disregarded and have contributed to complex and confusing flows. Lauri Koskela summarizes the principals required for the enhancement in efficiency of these flow processes:

1. Reduce the share of non-value-adding activities (also called waste).
2. Increase output value through thorough understating of customer requirements.
3. Reduce variability.
4. Reduce cycle times.
5. Simplification of flow processes by minimizing the number of steps, parts and linkages.
6. Increase output flexibility.
7. Increase process transparency.
8. Focus control on the complete process.
9. Continuous improvement of the processes.
10. Balance flow improvement with conversion improvement.

The traditional construction approach emphasizes on what the client wants as a finished product. Lean methodology stresses that the final product is as important as the why it is being built. The methodology wants to dig deeper and truly understand the customer’s point of view and establish a relationship which will enrichen all the stages of the project. Identifying value from the customer’s point of view brings together all of the stakeholders from the get-go and enables for everyone to be on the same page.\[12\]

Once value is understood from the customer’s point of view, the different processes required to achieve the goal must be laid out and analyzed. Value stream mapping is a flowchart method that illustrated, analyzes and improves the steps required to deliver a product or service. This technique is especially useful to find and eliminate waste.\[13\]

The major types of waste that Lean construction tries to undermine are the following:\[14\]

1. Defects

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• Defects may stem for various reasons and have a direct impact on quality and cost. It results in reworks and cost overruns of the total cost but also includes the associated costs of re-inspecting and rescheduling.\cite{15}

2. Overproduction
• Overproduction is caused when the production of a material is greater than the required quantity. Its root cause might be quality problems, unnecessary documentation, or even competition for a limited resource. Overproduction serves as a mechanism by which the company ensures that the customer order has been satisfied. Overproduction may cause wastage of materials, working man-hours and also equipment usage.\cite{16}

3. Not utilizing talent
• Not utilizing talents refers to the range of skills and expertise that may be undermined in a construction project. Personnel being matched with tasks that hinder the optimizing of the project.

4. Transportation
• Transportation (or motion waste) is shaped by the moving of materials either on site or while transporting it to the construction site. The logistics must be coordinated in such a fashion that it does not interrupt the work flow and that the scheduled deliveries are executed, as to avoid the incurring of a transportation cost.

5. Inventory
• Waste in inventory considers the materials that are not immediately needed. These materials require storage and tie the budget of the project, creating cost overruns. Inventory waste may be caused because of deficient planning or variations in estimated quantities.\cite{17}

6. Movement
• Waste of movement refers to the excess movement by people or tools and equipment’s which consumes time and resources. Movement of people concerns with unnecessary and inefficient movements made by workers during their working hours, ineffective methods and poor arrangements of work space.\cite{18}

7. Over Processing
• Waste of processing is caused due to doing something more than what is required. Complex process designs, redundant steps, over-engineered materials are just a few of the examples of activities that fail to add value to the customer.

8. Waiting
• Waiting waste is related to the idle time caused by lack of synchronization and leveling of material flows and pace of work by work crews or equipment.\cite{19}

The utopic state of a lean construction project is a continuous, uninterrupted workflow that is both reliable and predictable. Communication and team work between all entities involved is a key aspect to achieve flow. It is essential to minimize the time it takes for a message to come across from one party to another. Stakeholders have to be informed and updated on the conditions of the project so that decisions can be taken swiftly. Lean philosophy empowers the belief that it is necessary for processes and systems to evolve and continuously improve. Figure 2-3 is the representation of the 5 pillars of Lean methodology according to the Lean Construction Institute and serves a summary of what was explained previously. Noteworthy
how the words respect for the people are engraved in the background as to underscore the trying to scope a project in a more a humanizing manner rather than just another construction project.

Companies are embracing the Lean methodology since it maximizes value for the customer while minimizes waste. This approach is appealing since the construction industry is poignantly focused on budgets and timeframes while maintaining a level standard of quality that satisfies the client.\textsuperscript{[21]}

\subsection{BIM in Construction}
The construction industry is in the midst of a technology renaissance as companies are realizing the value that may be achieved by the correct implementation of technology throughout the different construction phases. BIM served as an initial catalyst that has sparked the sector to invest into software and technology solutions with the goal that these enable the company to compete and stay ahead of the curve. From laser scanning and virtual reality all the way to Big Data analytics.

The promise of BIM is to build a structure virtually prior to physically constructing it.\textsuperscript{[22]} This process allows project participants to design, analyze, sequence, and explore a project in a digital interphase where changes can be made without impacting the cost of the project in a radical manner. Planning and realizing the fallacies of the project before it has been erected is giving companies an extra step to verify the works and calculations without suffering any major consequences but the modifying of a digital representation of a structure. An array of BIM
software and mobile applications are delivering results that mitigate construction risk and improve the safety of the workers involved on site.

BIM is a cycle of continuous improvement and evolution that seeks optimization of the technology and processes applied on construction project. The methodology came into the scene with 3D models, but the construction community is seeing a shift from the 3D or visualization aspect of BIM to workflow-specific tools that are being directly applied to solve real-world problems, such as installation verification, sequencing, and estimating.[23] BIM transformed itself into a 4D tool that was able to take the time factor into account with the development of software such as Synchro Pro. The 4D aspect increased the pressure on contractors to understand the methodology since the digital model was not just a great selling tool but was becoming a useful tool in the planning of a project as well. Some software companies keep on pushing the boundary and are attempting to reach the 5D barrier which would also include all the costs associated with the 3D components of the model. Technically it is possible, but the industry still is battling with whether all of the work required to set in these inputs into the 3D model are feasible on a project, and if so, on what scale. The industry dialogue is now moving to a common questioning of how to optimize the effective capture, analysis, and dissemination of information in real time to make projects more successful through cloud services and mobile devices.

The value of BIM in construction derives in many shapes and sizes. Whether it’s the ability to save time through the automation of functions, reducing travel and meeting times as information is readily available, or cost reductions because a direct consequence of availability and quality of information is conducive to cost-effective decisions, they all have the same focus: results.

BIM continues to redefine the way the construction sector builds and works together. The core ethos of BIM is the ability to add useful information and adhere it a 3D model. Owners and companies must strive to ascertain how this stream and availability of information is applicable to their work and extend its use by giving it meaning for other related workflows and processes. Some of the basic processes impacted by BIM stem from basic functionalities such as estimating, scheduling, logistics, and safety. The methodology not only has pushed the boundaries on the insertion of information into visual elements but has demanded for an interconnectivity of this information to widen the reach of people that can access it. This interconnectivity has affected the surge of cloud services that are willing to rent some of their space so that a project can nurture within it but also useful tools within the software that allow easy imports and exports of the data. This partly explains the reasoning behind the creation of the Industry Foundation Classes (IFC) data model. IFC data model intends to describe building and construction industry data in a platform neutral and open file format specification.[24] The reasoning behind its formation roots from the necessity the facilitate interoperability in the architecture, engineering and construction industries. The BIM boom of the last few years has incentivized technology companies to create programs that are BIM specialized and thus have their own platforms. This software competition got muddled up because each worked with its own rendering and 3D formats (Revit, ArchiCAD, Navisworks, Bentley, between many others) and thus the interaction between each other was minimum. Industry Foundation Classes aimed to solve this conflict by establishing itself as the standard by which these software could communicate. BIM has also propelled collaboration platforms such as box.com, Dropbox, Egnyte, Newforma, wetransfer.com.
BIM in construction has changed drastically the last decade in large part due to a renewed focus and energy in the construction market space. Software companies were able to insert themselves successfully in the design landscape and so shifted their focus to their next endeavor, construction firms. The logical sequence opted by these tech companies was based on product deployment because of immediate value, in some ways the order of deployment from these more design-focused tools to construction was a “beat to fit” solution.\textsuperscript{[25]} The industry is presently quashing some of the initial assumptions like the belief that the tools designers used would also fit the needs of the construction teams. The software approach was refocused by looking specifically into how BIM applications can create value as a tool for construction to achieve better results. Software industries enhanced modelling tools to account for this reshaped interest of capturing the attention of big construction firms looking to apply technology solutions into their traditional paper and pencil methodology. These tools are swarming the market as competition deepens to see who can create the tool that best suits contractors and hence win the market share.\textsuperscript{[26]} The tools are fixated on ways of finding and coordinating construction as well as automation of the information exchange from 3D models to management features such as estimating, scheduling, monitoring, quality control. An example of this may be appreciated in Figure 2-4 which demonstrates how BIM applications have been favoring the design phases over those proper of construction and operations and management.

Large software vendors have created software that is generic and malleable enough so that it may be coded to serve the specific needs of a company. This means that a specific software may advertise itself as capable of a certain task but in reality, it just means that it has achieved this task in a specific scenario and under special circumstances. The dissertation paper provides insight into how some of these available BIM tools can be used on the areas in which software still needs to develop to bridge the gap between design and construction. The software that

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure2-4.png}
\caption{BIM application in a project’s lifecycle\textsuperscript{[27]}}
\end{figure}
were used for this paper were tools meant to be used by construction firms and have been tailored to accomplish what is required of a Construction Management company.

2.2.3 Level of Development

The Level of Development (LOD) of a project is a crucial aspect that must be agreed amongst the different entities involved. The LOD will define the quality of the 3D model created, the BIM scope of the project, the elements that the client absolutely must have detailed to the highest of standards; basically, the objective of the BIM implementation will be shaped here.

A model will never be characterized by being a “LOD ### model” because the model will vary within the project delivery stages. The 3D model may start as a LOD 100 model at its origin but develop into a LOD 200 model when construction phase is set to start. However, LODs are not defined by design phases but by the design phase completion. The main reasons why this approach is valid is because there are not detailed standards for the design phases as it changes from company to company. Another logical reason to support the claim is that building systems progress from concepts to accurate definitions at different rates, different set of elements with be at different points along the progression at a given time. In other words, at the completion of the schematic design phase, the model will contain elements that are LOD 200 while others with LOD 400. The key difference between Level of Detail and Level of Development is that the latter stresses the degree to which element’s geometry and information is thought through and not just the detail of the object. The Level of Detail can be amusingly high on a generic component brought from a software’s library, but its Level of Development will not take this into account unless the author has inserted data pertinent to the project at hand (geometrical exactitude or attached information).

The LOD schema presented by BIMForum addresses several issues that may come about when a BIM model serves as a collaboration and communication tool; specifically, when someone other than the author extracts information from it. When the author is creating the 3D model, the systems that conform the model evolve from a vague concept to a precise description. It is often difficult to measure the exact point in which the element is along this creation path; the author may know but others will not. Another obstacle is that the digitalization of models enables the designers to choose a component that may seem to be detailed when it still is not in the project. Software like Autodesk’s Revit contains a library of objects and components that may be chosen and are shells or hollow in terms of information but, at a first glance, seem to be complete and precisely detailed. This hindrance has presented itself in the last few years since the power of these software allows authors to use components stored in the libraries, it is easy to confuse a completely detailed component from a generic one. In a collaborative environment, where people other than the model author are reliant on information from the model so they can perform their own work, the design work plan becomes a focal point. People that will extract and use data from the model need to know when the information will be available.

The standard Levels of Development used in BIM are presented both textually and graphically in Figure 2-5, so the reader can grasp the totality of the definitions, these LODs are:

- LOD 100
  - LOD 100 elements are not accurate geometric representations. Objects may be represented with a symbol or other generic depiction, information related to the object might be derived from other modelled elements.
- LOD 200

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LOD 200 elements is graphically represented as a generic system, object or assembly with attached information that must be considered approximate.

- **LOD 300**
  - LOD 300 elements are geometric representations of the objects that may contain detailed information within the modelled element. The quantity, size, shape, location and orientation may be deduced from the element.

- **LOD 350**
  - LOD 350 elements are geometric representations of the objects and contain information of the interfaces (borders, connections, supports). The quantity, size, shape, location and orientation can be directly measured from the modelled element.

- **LOD 400**
  - LOD 400 elements are geometric representation of the object and contain information regarding detailing, fabrication, assembly, and installation information. At LOD 400, an element is sufficiently detailed whereas measurement can be made directly without referring to notes or dimension callouts.

- **LOD 500**
  - LOD 500 elements are modeled as built congregations, for instance, exact as far as amount, size, shape, area, and introduction. This last LOD comprises information as constructed including as-built conditions. LOD 500 components incorporate finished parameters and qualities point by point in the owners BIM deliverable determination.

![Figure 2-5: Example of LODs on a structural kicker](image-url)
3. Methods

The major objective of this dissertation paper is to create a methodology on how to implement BIM software on construction management applications. The approach taken to achieve the objective was to become fluent on two different BIM construction software (BIM 360 and Synchro) and utilize them in the Foc Cisell station. The implementation of these two software was unique since they have never been used strictly as a construction management tool but as an instrument for general contractors. The big technology firms behind these software (Autodesk and Synchro Software) created these programs to try and infiltrate the construction industry. Taking these products and enabling them to serve functions proper of a construction management company was the most challenging aspect of the research as their innate design is to succeed at aiding basic general contractor’s activities. Autodesk’s BIM 360 played a bigger role in QA/QC as will be explained later because of the incredibly flexibility and user personalization capabilities within whilst Synchro provided to be a necessary tool for planning and monitoring of elements and tasks of the project. The implementing of these tools took place in the Foc Cisell station of the L9 project during the months of August 2017 through April 2018. A specific pilot project was carried out for each of the software which entitled Autodesk support as well as AECon for Synchro in Spain.

The dissertation paper is based on this project given the author’s proximity and knowledge of this construction project plus it’s one of the most important heavy engineering projects nowadays in Spain. The joint venture responsible for most of the construction performed on the various stations comprising the metro line is constituted by three construction firms. One of these firms is driven by I+D and paving the way into its future and decided to create a 3D model for one of the subway stations, Foc Cisell. This key decision facilitated the research as all the work performed on Synchro and BIM 360 uses this 3D model as its cornerstone. The big picture vision of the investigation was to measure with key performance indicators whether or not these programs benefitted construction management firms when correctly implemented with proper training of the personnel and on the right environment. The study sought to find out whether these software and the inherent digitalization offered enough pros to outweigh the cons. The particular approach undertaken to create this dissertation paper was freely chosen as there is no such research on the topic.

The research was conducted by choosing mundane day to day processes and tasks and attempting to replicate them in both or either of the chosen software. The study wanted to understand if day to day construction management chores could be automated and digitalized; if possible enhanced to provide a better output. The pilot project had to be engaged by assuming that all the selected tasks were to be executed in a given software and there had to be a plausible way to achieve this with the tools the platform provided. This key aspect opened the doors for creativity and thinking outside the box since all the documentation and various functions required by the client were to be available and complete whenever demanded. Regardless, all of the construction management tasks were also fulfilled using the old and typical tools as stated in the Quality and Environmental Control Plan.

The architectural and MEP systems were emphasized in the research because the 3D model had a higher LOD for these. Within the MEP system, the Fire Suppression System was of upmost importance to the client and hence was selected to address these concerns and priorities. The project also deepens its investigation in subjects relating to quality control/ quality assurance and documentation since these are areas where the construction industry lags and

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really needs an extra push. The author of the paper is directly involved in these ambits, so it adds an extra dimension of knowledge since it’s the same person handling the traditional methods of doing things and the state of the art software’s methodologies. Figure 3-1 is an image of the author on the Foc Cisell station applying some of these cutting-edge methodologies using an iPad which will be explained in the latter chapters.

Figure 3-1: Author on Foc Cisell station applying BIM 360 methodology on iPad (Author)
4. BIM 360 Methodology

4.1 BIM 360 Platform

Autodesk’s BIM 360 serves as a cloud service that attempts to connect the construction project lifecycle. BIM 360 improves the construction project delivery processes because it provides the tools that invoke informed-decision making as the platform emphasizes the need for data to be constantly updated and well-structured. BIM 360 connects the people, data and workflows on a project, from design collaboration through document reviews, all the way to quality and safety inspections in the construction phase and as-built documentation for operation and maintenance. BIM 360 challenges the general notion that a construction management software is only capable of excelling on a specific phase of a project’s lifecycle.

Autodesk BIM 360 is a comprehensive project management platform designed for the construction industry. The software aims to help speed up project delivery schedules while staying within project budget and adhering to industry standards, safety regulations, and project specifications. The software empowers managers by allowing them to coordinate staff actions, implement workable schedules, improve communication between teams and companies, resolve issues and non-conformities; all of these in a digitalized environment with real-time information. BIM 360’s advantage heaves from the fact that the software is flexible enough that it can accommodate different types of companies from the construction sector. This is one of the prime reasons for choosing BIM 360 for the investigation as this versatility was required to create a methodology for an established construction management firm.

The Autodesk BIM 360 platform is composed of 7 products whose emphasis varies to account for the needs of a construction firm. Figure 4-1 displays the available packages within BIM 360 and contains a brief description of the capabilities and scope of each product.

![Figure 4-1: Autodesk’s BIM 360 products](image)

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The most potent products within the BIM 360 family are the ones of BIM 360 Glue and Field. This knowledge was garnered after working besides many Autodesk support personnel and after performing intensive research on the applications of these products on projects around the World. The vast majority of the products mentioned above in Figure 4-1 are developmental and still haven’t played their expected role in the BIM 360 scheme. The dissertation paper used BIM 360 Team, Glue and Field to achieve all its set activities and aspire to attain its goals.

The BIM 360 platform is a cloud-based common data environment, meaning that the exchanging of project data between the 7 products goes without cumbersome exports or time-consuming steps. Some of the data may be instantly shared across the users and the team by using a web browser at the office or a mobile device from the field. It is of upmost importance to understand that it is not a requirement to put into service all 7 of the products on one project, a company may choose to work with the ones that serve its need. The programs are destined to serve a specific phase of the construction lifecycle and even include some duplication of functions so that every program “goes that extra mile” and grasps more than its scope. Figure 4-2 positions the products amidst the construction project lifecycle. As mentioned previously, for the L9 Foc Station Project, BIM 360 Team, Glue and Field were the products implemented. The thesis paper will mention the manner in which information may be exported and used in the maintenance and operations stage but none of the objectives included the managing of data once it was exported but to manage and optimize the day-to-day tasks entailing a construction management firm working on a project.

For more information on the author’s involvement with BIM 360 in his company refer to Annex 2 that explains his divulging of lessons on the topic.

Figure 4-2: Autodesk’s BIM 360 products by construction phase
Out of the three Autodesk BIM 360 products used in the Foc Cisell Station Project, the two deemed essential for the correct implantation are BIM 360 Glue and Field. The next section will cover the basics of these programs and their employment in the project.

Before jumping into BIM 360 Glue and Field, which were more involved in the pilot project than any other BIM 360 product, a brief mention of BIM 360 Team will be written since its capabilities are noteworthy and may be suitable for other projects.

4.2 BIM 360 Team

BIM 360 Team’s purpose is to alleviate common mistakes associated with the collaboration and document management in the design phase. Some of these common mistakes include working on an older version of the document or even not finding a contractual document. The way Team operates is by storing the entirety of the project data in one location and allowing anytime access to any permitted user via cloud access. Documents may be viewed, shared with users and interdisciplinary teams, marked-up with automatic notifying. The 3D viewer inscribed into BIM 360 Team is was tested multiple times in the Foc Cisell station with both Revit and IFC models and proved to be competitive as well, meaning that users without these software can still visualize them in Team. An offline mode is also an essential feature embedded in BIM 360 Team as users can access the models with mobile devices while on-site without a stable internet connection. Figure 4-3 displays some of the features mentioned for BIM 360 Team. These images offer visual explications of the manner in which the software may be applied. The first screenshot is an image of the folder structure used for the Foc L9 Project. These folders were utilized to segregate the updated models by their creation date. The second image displays the viewer embedded into the product that allows for some of the same functions as BIM 360 Glue in terms of reviewing and analyzing.
4.3 BIM 360 Glue

BIM 360 Glue is the product that handles pre-construction interactions except for documentation. This program is powerful by itself with its many tools that will be later explained, but its true influence in the BIM 360 vision emanates from the fact that it is the first stepping stone needed to use BIM 360 Field. This last statement is fundamental because the word glue might make people believe that its purpose is to glue and merge different models and seek for clashes, however this glue also refers to the bridging of products by gluing and preparing the model for the monster of BIM 360 Field. Once the products are explained, BIM 360 Field will shine and the word monster will make more sense.

BIM 360 Glue is a software that may be worked directly from an ordinary web browser or download as a desktop program. The web browser offers visualizing features and may be accessed by anyone with a valid license or by means of a free trial, whereas the desktop program is meant to be downloaded via a direct invitation from a project administrator or account administrator. The desktop program is set with more instruments and is required to create equipment sets (key stride to get to BIM 360 Field).
Figure 4-4 below summarizes the potentials of BIM 360 Glue. This software allows users to access the 3D models (either individually or merged) wherever they may be, even on offline mode which is especially useful whenever on a construction site. Model navigation is user friendly and features various options that further enhance this such as walking through walls and creating views to start at a specific point inside the structure. The integration with Navisworks is simple as the publishing of models can be performed by just clicking a button. Notifications can be sent to users and entities involving the project even if they do not possess the desktop program or a valid license, this characteristic is vital as many subcontractors may not have the size and resources to purchase a license for a project. Markups work exactly the same as notifications; users receive an email notification and they are taken to the exact 3D location where the markup was created.

<table>
<thead>
<tr>
<th>3D Model Access</th>
<th>Constructability Review Tools</th>
<th>Simply Navigate Models</th>
<th>Measure</th>
<th>Design Tool Integration</th>
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<tr>
<td>• Anytime, anywhere access</td>
<td>• Review and annotate models</td>
<td>• Gesture-based pan, zoom and orbit</td>
<td>• Point-to-Point tools</td>
<td>• Upload directly to Glue</td>
</tr>
<tr>
<td>• 5D+ file formats</td>
<td>• Send notifications to project team</td>
<td>• Gravity-assisted walk through navigation</td>
<td>• Object snapping</td>
<td>• Automatically manage model versions</td>
</tr>
<tr>
<td>• Sync models for offline viewing</td>
<td>• Respond to markups</td>
<td>• Select, hide and reveal model components</td>
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</tbody>
</table>

BIM 360 Glue accelerates constructability reviews and empowers the process of identifying and resolving issues in the preconstruction phase. The workflows are designed so that multidisciplinary teams can set forth concerns before they may materialize and affect the budget and schedule of project. Figure 4-5 illustrates the standard Influence vs. Cost Curve graph that exemplifies how the detection and mitigation of issues is at a minimum during the preconstruction stage.
4.3.1 Integration and Merging of Models

BIM 360 Glue offers the means to centralize different BIM models in a simple and user-friendly manner. This merging of models is especially useful as it accepts 3D models originated from virtually anywhere. The recommended methodology to import a model into BIM 360 Glue is to install the official add-in from the Autodesk website for the software containing the model. Once the add-in is installed, the model can be sent into Glue after hopping through some inputs required to configure the model fittingly. Individual 3D models can be selected and merged to obtain a singular model that suits all the systems, allowing for a project-wide clash detection. Anthony Neal, one of Autodesk’s primary support agents based in London, endorses that 3D models be imported as is instead of converted into IFC format. The reasoning behind this is that BIM 360 Glue requires a set of properties to remain constant regardless of when it is imported and the generation of IFC models via Revit has been shown to impact this process by adding a set of random numbers after the element’s family name. The obstacle here is that the ability to group by name is hindered and the creation of equipment sets becomes more difficult. Figure 4-6 is a screenshot taken to demonstrate how both approaches were taken when merging the 4 models available. The first method was handled by merging IFC models and the end result is the one titled “FOC L9 IFCs” and the second attempt involved Revit models and its unification produced the document “Merged Revit”. Figure 4-7 displays the merged Revit model which was the one used throughout the development of the pilot project. The exact view depicted is one where both the structural and environmental layers are hidden to gain a greater insight into the architectural and MEP features.
The Foc Cisell Station Project experimented with both IFC as well as Revit formats. The first iteration was ran using IFC models as it proved to be easier to upload into Glue and hence seemed like the logical choice. The 4 models that comprise the coordination model (Architecture, Structural, MEP, and Environment) were uploaded and merged using the same methodology previously explained. Measurements were made to verify the validity of the models and markups were created to notify third parties about potential issues seen in the 3D model. After encountering the grouping problem described above, the author decided to link directly the model from Revit into Glue as was suggested by the Autodesk personnel. The Revit models were merged and a clash detection was performed. 3D views were created to ease the

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manner in which the user navigated the model (especially when using the iPad which will be developed later). 3D views were created for all of the station’s stories as well the technical throughout the station. The drive behind this was to have a 3D view for every location in which there was an equipment or asset included in the Equipment Sets. Figure 4-8 shows the views created for the Foc Cisell station which are organized by stories to facilitate 3D navigation. It is interesting to note that the author decided to create views for non-conformities as this would allow non-experienced BIM 360 users to get to the exact 3D position where an issue arose.

Figure 4-8: 3D views created for the Foc Cisell Station (Author)

4.3.2 Clash Detection and Avoidance
Clash avoidance and detection plays an important role within the capabilities of BIM 360 Glue. Glue helps teams run multiple clash detections on a merged model so that everyone within the project can be up to date with potential element clashes. The software allows the users to set tolerance levels depending on the precision for which the clash review is taking place. The program identifies the clashes and lists the elements for which clashes are currently occurring, by clicking on the clash it redirects the windows towards the 3D elements responsible for the clash. Filtering tools are available so that a clash detection review can be set for specific
systems, users, discipline, and other options. Figure 4-9 exhibits a clash detection result set and set the example of how clicking on a clash automatically redirects the user towards the problematic objects, in this case a segment of the tunnel section colliding with a wall. This image was taken so that the user can sense the importance of the tool within the product.

Figure 4-9: Clash Detection Review performed on BIM 360 Glue (Author)

The pilot project executed for this dissertation paper did not immediately require a clash detection since the BIM 360 application took place during the construction stage. The only reasons clash detection reviews were conducted was to make sure that the models had been merged using valid coordinate systems and that no major issues would arise later on while using BIM 360 Field. The clash detection tool was compared to that of Autodesk’s Navisworks but was not able to compete with it as Navisworks is a software that dedicates all of its resources to this one task. The identification and review of clashes was not as accurate as Navisworks plus the customization options also compared poorly. Figure 4-10 was generated by feeding the 4 individual Revit models into Navisworks and merging them into a single integrated model. The coordinated model was then scrutinized with the almighty clash detective Navisworks offers and the results are shown in this image. The main reason for this clash detection review was to compare and contrast the two different software. This figure illustrates the clash of an escalator and a slab.
4.3.3 BIM 360 Glue connection with BIM 360 Field

BIM 360 Glue is a central piece if a company wants to utilize the product BIM 360 Field. BIM 360 Field will be explained later in the paper but for now just believe that its constant mentioning has an underlying fundamental reason. Glue allows users to create Equipment Sets which is the equivalent of bridging the gap between Glue and Field. When the initial BIM Execution Plan is being constructed, the elements that require special detail and attention are listed so that they can be modelled in whichever drawing software is used. Another similar list (or might be the exact same) must be brainstormed to account for the elements and systems that want to be managed throughout the construction phase. Managed is a broad term that encapsulates and that is the intention behind using it. This list should embrace the components for which the client, general contractor, construction management firm, design firm, subcontractors believe that attaching information is worth the time. The information may come in many shapes or forms, from inspection guidelines needed to create checklists associated to groups of components all the way to PDF documentation relating to material approval submittal, material sheets, specific testing protocols for the asset, material testing results; even simple photographs that to demonstrate the status of an asset. Once the list is fashioned, the Equipment Sets can be created in BIM 360 Glue.

The models drawn for the Foc Cisell station emphasized some systems over others based on the client’s preference which was easily distinguishable by the LOD. When the 4 Revit models were merged together, the project architect and MEP engineer of the construction management firm were summoned to discuss which elements necessitated a deeper monitoring and management. The original architecture model contained fewer elements and these were drawn with lower LODs than the MEP one and this is reflected in the quantity and quality of elements selected for each discipline. The project architect decided that he was interested in the
following elements: two leaved door, ceramic tiling, Barcelona railings. The MEP engineer underlined the importance of the Fire Suppression System and this is reflected in the elements selected: ventilation fans, fan silencers, fire extinguishers, fire dampers, pressurized system, smoke detectors, sirens, fire alarm push stations, fire control units, and other smaller devices. Table 4-1 displays the entirety of the elements that met LOD 300 requirements in their modelling. These elements represent the pool of components and systems that had to be chosen by the author to execute the pilot project.

Table 4-1: Elements modelled under LOD 300 used in BIM 360 Field (Author)

<table>
<thead>
<tr>
<th>LOD</th>
<th>Fan Silencers</th>
<th>Fire Dampers</th>
<th>Regulators</th>
</tr>
</thead>
<tbody>
<tr>
<td>300</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LOD</th>
<th>Impulsion System</th>
<th>Return System</th>
<th>Ventilation System</th>
<th>Primary Air System</th>
</tr>
</thead>
<tbody>
<tr>
<td>300</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LOD</th>
<th>Air Grilles</th>
<th>Deposits</th>
<th>Pressurized System</th>
<th>Valves</th>
<th>Devices</th>
<th>Pipelines PCI</th>
<th>Stopcocks</th>
<th>Fire Sprinklers</th>
<th>Firefighting Systems</th>
<th>Fire Extinguishers</th>
<th>Fire Control Unit</th>
<th>Smoke Detectors</th>
</tr>
</thead>
<tbody>
<tr>
<td>300</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>
</tr>
</tbody>
</table>

4.3.4 Equipment Sets
The Equipment Sets were generated by grouping elements of the same nature that were to be configured and eventually managed under the same set of standards. This meaning that if exact components were set in different locations of the station, the author could choose whether or not to cluster them together. The significance of this is that it is a possibility that some of the documentation is shared between these and doing so does not curtail attaching checklists and documentation to specific elements within the cluster once the construction phase began. The grouping of elements was executed by both Name and Types depending on which suited better the way that the elements transposed into BIM 360 Field. Figure 4-11 are the Equipment Sets extracted from BIM 360 Glue and eventually pushed into BIM 360 Field. These were created founded on the elements available under the LOD 300 umbrella and where either grouped by Name or by Type which is why there are letter “N’s” and “T’s” next to each set.
4.3.5 Workflows and Channels of Information

The 3D model integration use case follows the pattern of Figure 4-12 as the BIM model is the principal carrier of information throughout the construction phase into the operation and maintenance cycle. The data generated through the construction of the Foc Cisell station must be prepared for digital client handover since this information will be used for years to come by the company responsible for the commissioning of the subway station. This case caters for the following digital work flows:

- Digital As-built information collection to allow the client to effectively operate the assets post-handover. This information linked to the BIM model includes inherent element characteristics as well as serial numbers, installation dates, issues produced during its creation or placement, status history for the equipment with specific dates,

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documentation attached to specific objects, barcode associated to the element, tag numbers, as well as any custom property that was created for the project (digital signatures used for the pilot project).

- Checklists and inspection information linked to BIM model to provide complete and useful digital handover to the client for its operation. These checklists can also be personalized to surmount for important project characteristics such as making the general contractor digitally sign the inspection or automatically triggering email notification when a checklist generates an issue or non-conformity.

- Issue tracking information linked to the 3D elements and systems conveys a big picture vision and allows the client to manage these issues during the commissioning phase. This issue section will be further developed in the paper since much was executed to grasp other activities within the scope of a construction management company.

- Documentation was handled via the digital library available in BIM 360 Field which can be easily exported to deliver all the generated documents to the client for managing the post-construction stages. A detailed registry of when the documents were added and modified is also exported so that the archive navigation is simplified.

The workflows the way the pilot project was conducted are presented in Figure 4-12. These flows represent the importing of models and information into BIM 360 Glue and the resulting generation of data in BIM 360 Field, stemming from on-site reporting on the iPad application as well as the tasks handled from the office. All this information can either be translated into the original BIM model for updating required or, and most notably, brought forth into another software as part of the concluding of the construction phase.

![Figure 4-12: BIM 360 Glue and BIM 360 Field workflows](image-url)
4.4 BIM 360 Field

BIM 360 Field is a construction site management tool that allows those in field to act based on the latest information via mobile devices. The information is uploaded into the cloud which then enables those in the back office to manage and control construction performance. The objective of Field is to digitalize many of the on-site processes that are currently executed on paper. BIM 360 Field serves as the banner product for BIM 360 as it is the software whose capabilities match the desires of general contractors seeking for an optimization of on-site activities.

BIM 360 Field improves labor productivity by empowering site processes to be performed via mobile devices which eliminates the need for paper recording and the interaction of redoing the work on a laptop to report an inspection, issue, or even occurrence.

The L9 Foc Cisell Station was implemented with the purchase of an iPad that permitted the author to apply the distinct processes being explored while on the job site. The advantage of the digitalization of these processes were immediately perceived as the author travels in bicycle around the city and the toolbox was reduced to just a small tablet that contained all the data in the most portable of manners. The iPad was the main instrument to conduct inspections, resources status verifications, daily updates and document the general site progress through photos. These applications will be explained later in the dissertation paper. Figure 4-13 portrays the author while conducting a routine equipment inspection for the escalators. The image demonstrates how the iPad enables the inspection of specific elements either via its associated checklists as well as the viewer.

Figure 4-13: BIM 360 inspection conducted by the author (Author)
4.4.1 Eliminating Waste in Rework of Information
The product is keen on minimizing double entry of information. When a process is performed on the tablet application, the activity is automatically uploaded to the cloud and can be set up so that other users and teams are instantly notified. The person responsible for conducting the process will not have to return to its office to retype the process into excel or word. It is important to state that any item being uploaded into the cloud can be reviewed before its immersion, this allows the user to verify the correctness of what is being uploaded.

The L9 project involves the generation of numerous documents whenever a site visit is conducted by the construction management joint venture. These visits can be as simple as daily inspections held by the principal inspector or official memorandums of visits taken place by interdisciplinary teams. This project requires the filling of monthly TPIs for architecture, heavy engineering, mechanical electrical and plumbing and quality which are shepherded through BIM 360 Field’s checklists. The latest set of approved drawings were uploaded into the product’s Library and managed by these means. All the processes mentioned above fit the description of processes that must be worked twice to obtain a single result. The tasks are executed on site using paper and pens and then have to be transcribed into the computer to either archive or send to other participants. Figure 4-14 is an example of a typical monthly quality inspection that the client requires for the construction management firm to perform. This document is first executed on-site manually using paper and pen while taking photographs with the cellular phone. Once the author returns to the office, the information is digitalized in Microsoft Word so that it can be attached in the monthly quality and environmental report. Figure 4-15 depicts the situation when the author performs the quality inspection utilizing the iPad and attaching images to specific line items. This second example eliminates rework as the checklist is uploaded into the cloud and notifies whoever requires the information.
Figure 4-14: Example of a quality inspection that had to be transcribed into Microsoft Word (Author)

<table>
<thead>
<tr>
<th>ID</th>
<th>000001</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>Control Pla de Med Ambiente En Cita</td>
</tr>
<tr>
<td>Status</td>
<td>Open</td>
</tr>
<tr>
<td>Priority</td>
<td>Medium</td>
</tr>
</tbody>
</table>

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Figure 4-15: Example of the same quality inspection as Figure 4-14 executed as a BIM 360 Field checklist (Author)
4.4.2 Improving Quality through Checklists

BIM 360 Field improves quality and reduces the cost of rework by tracking quality inspection and testing plans using configurable checklists as mentioned previously. These checklists are meant to be filled while on the construction site while standing in front of the source of information which closes the gap between the emitter and receptor of information. Checklists can be suited to meet different objectives and disciplines such as running testing protocols for an individual equipment or a quality inspection of the storage of materials.

These checklists were thoroughly utilized to serve various disciplines and purposes in the project. The checklists created had the ability to auto-generate issues whenever the input answer did not comply the standards imposed by the construction management firm. Figure 4-16 is an example of one-line item inspection that failed to meet the quality requirements and thus was flagged as incorrect, hence triggering and generating an issue. The author attached an image that validates the reason why the line item was set as incorrect. This image would also be placed within the generated issue so that its managing would be simpler.

![Image](image.png)

Figure 4-16: Line item inspection whose response “incorrect” triggered and created an issue (Author)

4.4.3 Promotion of Safety

The product promotes risk analysis and improvement of safety by providing digital recordings and a review interface in which teams can monitor the safety procedures while on their desk at the office. This documentation can be uploaded and stored in the software while setting various levels of permissions by users and companies to eliminate leakage of confidential information.

In this project the principal step taken behind the scope of safety was to upload the official Occupational Health and Safety Program approved by all entities involved. This document was given special treatment as a bar code was associated with it which meant that whenever it was scanned, the user would be redirected to the PDF document. The barcodes will be explained...
further along the line, but they carry a crucial load in the accessibility of BIM 360 Field. Figure 4-17 illustrates the manner in which a QR code redirect the user into the uploaded Occupational Health and Safety Program.

![QR code and the Occupational Health and Safety Program](Author)

Field enhanced the connection of information between the construction and commissioning phases since the system and equipment information may be exported and linked with other software. The data associated to the assets can be viewed digitally which saves time and reduces errors. Teams can access and view photos, operation and maintenance manuals, manufacturer datasheets and specifications and much more.

### 4.4.4 Automation of Reports

BIM 360 Field engenders management and monitoring solutions with its tools aimed at automating and field performance through detailed reports that can be arranged to be produced every certain interval in time. These reports can be customized so that they serve a purpose for any field management activity executed on the product. The reports are sent to the companies and teams whose participation is deemed to be relevant. In the case of this project, the reports were fundamental as they came to substitute weekly emails and memorandums that the construction management company had to submit to the client. The reports that had a more prominent role were those of issues as these could be personalized to signal the exact point of the disruption on official 2D drawings and the one corresponding to checklists as they could display the statistics behind the completion conformance. These reports would then be sent to the associated emails of the members of the discipline that aligned with the category or root cause of the issue. Figure 4-18 is an extract of an issue report for non-conformities in the Foc Cisell station. The image is pointing to a non-conformity (type of issue) with its specific pin placement on the 2D drawing plus its status. The report also adheres the documentation behind this issue, in this case both the official document behind the non-conformity by the general contractor as well as the construction management firm.
**Figure 4-18:** Extract of an issue report that display a non-conformity with attached information (Author)
4.5 Straying from the Path and Creating a Methodology

The implementation of the BIM 360 products on the L9 Foc Cisell Station ran into certain obstacles that had to be overcome through out of the box thinking and creativity. BIM 360 Glue is more brittle and had to be utilized by the means offered by the software’s designers even though some twists were explained before like the one of grouping elements by Name or by Type. BIM 360 Glue played its role of serving as a launching pad for which the author could exploit all of the utilities available in BIM 360 Field. The main features of BIM 360 Field were already mentioned previously and the manner in which they were applied in the pilot project, but the more interesting processes and methods were reserved for this section to try and ripen them as much as possible.

The way the project collected and stored its information was through the use of an iPad with 4G capabilities and its interconnectivity and the BIM 360 cloud service. Most of the configuration work was performed while on office and then the actual execution of the activities on-site. Figure 4-19 serves as a representation of the connectivity flows between the three main data sharing participants. The inputs are typically obtained by means of the iPad and the computer is responsible for booting of the project and eventual extraction of the gatherings.

The way the formatting of this next section goes is that the different modules within BIM 360 Field are presented and then the contributions and unique properties invented by the author are explained. This means that the next subchapters all represent sections that fall beneath the BIM 360 Field scope in which the author was able to meddle its way through and create a method, function, or anything really that the program did not foresee. These novelties were thoroughly discussed with Autodesk personnel in London to ensure that these ideas were not being implemented in any other project around the world.
4.5.1 Library

The BIM 360 Field Library is more than an ordinary storage and registry of documents. The Library serves as an active player than enables other features that will be explained throughout the next sections. The Library consists of folders and documents that can either be created simultaneously or uploaded as a complete folder structure with a special BIM 360 extension. The Library offers 3 intriguing features that were commonly used:

- Linking documentation with locations
- Attaching tags to the documentation
- Creation of barcodes for documentation

**Linking documents and locations**

Instrumental feature as it is the only way that permits the pinning of Issues on 2D drawings. Active documents that will be used on-site must be linked to a location which allows the tablet user to generate Issues on the drawing and these are coded under that location. The way that the documentation is connected to the specific locations is by accessing the BIM 360 Field Library and selecting the Actions button and then selecting the appropriate location from the location structure previously configured by the user. The way these links were applied to different Issue Types will be developed under the Issues’ subsection. Figure 4-20 displays a typical 2D drawing that has been connected with a location as its purpose stocks on its capacity to receive 2D pins.

![Figure 4-20: Locations associated to a 2D Drawing](Author)

**Tags and documentation**

Tags play a minor role as they do not support and per say unlock any other feature once applied. Tags may be perceived as a powerful filtering mechanism as they allow the user to invent any type of key word and then bond documents to it. The tags created for the L9 Foc Cisell Station are displayed in Figure 4-21. These tags were created by the author for accessibility purposes as navigating around the Library proved to be a time-consuming task. The figure below shows
what it looks like when tags are selected for a specific document, in this case being a 2D drawing used for the Sound Pressure Level Measurements.

![Tags created for the Foc Cisell Station Project](image)

**Figure 4-21: Tags created for the Foc Cisell Station Project (Author)**

**Barcodes in documentation**
Barcodes in documentation allow the user to quickly access any document without having to immerse itself in the Library. The barcodes act as a shortcut if managed correctly, an entire folder structure in one’s computer could be dedicated to a project’s barcodes. The iPad application contains a barcode reader that allows transports the user to the documentation regarding the scanned QR and/or linear barcode. The author created barcodes for documents that ranged from regulations and design guides, to individual asset information and even documentation related to material testing.

### 4.5.2 Companies
The BIM 360 Field implementation conducted internally by the author and its company as the information resulting from the project is valuable. The author decided to set up the companies as if they were completely involved in the project by creating gemails and making sure that all of the product’s capabilities were functioning as well as studying the communication interfaces (Figure 4-22).

![Companies created for the Foc Cisell L9 Project](image)

**Figure 4-22: Companies created for the Foc Cisell L9 Project (Author)**
4.5.3 Reports
The Reports tool attempts to digitalize and normalize documentation generated whose source of information stems from user inputs on BIM 360 Field. This tool is responsible for producing documents based off the information available within the cloud. These reports offer great flexibility as they can embody information ranging from Issues to Checklists and Equipment as well as various report templates that the user can configure and set as its own. The key function of the reports is the capacity to substitute double entry and rework of information as these reports may be scheduled and automized so that they are sent to all the participants involved in the topics of the report. The method the author utilized the reports within the pilot project will be described within the sub-sections of the Issue Types. Figure 4-23 serves a visual representation of what the author explained above; these are a set of templates available whenever selecting an Issue Report.

4.5.4 Project Overview
The Project Overview tab is the main viewing screen when accessing BIM 360 Field through a computer’s web-browser. This window is responsible for showing statistics and data relating the information that users have inserted onto the product. These statistics can appear in bar graphs, pie charts, cumulative trends, and other forms with the prominence that they can be personalized to display what the user wants. These diagrams work with filters so that users can see information corresponding to specific time ranges, Issue Types, Companies involved, and much more. The maximum amount of diagrams that may be displayed at a time are 5, the first one being the one displayed at the top of the screen as a percentile line graph that cannot be modified. The effect of the firmness of this line graph plays an active role within the creation of Issue Types and the manner in which the author assigned statuses as the graph could misinterpret information and mislead the users. Since these statistics had an incredible influence on the overall feel and the way users perceived the overall standing of the project,
the statistics had to be true and minimize statistical disturbances. The author had to brainstorm and come up with a system to avoid the adaptation of the creative Issue Types from impacting these diagrams and values, the approach will be described within the sub-sections of the Issue Types. Figure 4-24 illustrates the personalized screen used by the author to manage key aspects of the L9 Foc Cisell Station Project. As it may be appreciated in the screenshot, the author is heavily invested on the non-conformities and their root cause.

Permissions
The Project Overview tab may display information that is mundane to some and valuable to others. The manner that the software manages these permissions is by allowing the project administrators to configure the information displayed in these screens based on the user’s role. The author realized that generally the display screen was completely individualized and depended on the user, but by applying permission restrictions these screens could be tailored to display whatever benefits the user while safekeeping information from subcontractors and others. More than just the overall display of the dashboard or Project Overview, these permissions could be modified to restrict functions within the BIM 360 Field application. Figure 4-25 illustrates these functions adapted to what the author believed was best for the project.
4.5.5 Checklists

The Checklists module is arguably the most impactful tool within BIM 360 Field because of the amount of linkage that may be constructed as a direct consequence of its results. Checklists operate as the ultimate inspection toolbox for users on-site. These checklists can be set for any discipline and are customizable to an unprecedented level. Checklists are uploaded into BIM 360 Field through the means of an Excel template that the product provides and the user must fill-in, many of the columns are optional but the higher the quality of the Excel, the more features are unlocked and unleashed. Checklists could comprise an entire chapter in this dissertation paper, but the author thought that the Issues methodology carried a higher importance and level of creativity.

The Foc Cisell L9 Project created Checklists for several disciplines to try and encapsulate mundane activities such as QA/QC inspections conducted on the street level, all the way to the equipment testing protocols and material execution data sheets. The author’s involvement in these is maximum as he is responsible for completing these inspections and determining whether or not these meet the standards and regulations required. The most utilized Checklist is the QA/QC as the author is obliged to conduct one every month. This section will try to go over the normal workflow of a Checklist from its creation all the way to its application and results. The process will be conducted for one of the ceramic tiles so that the reader can focus its attention to a single element.

**Equipment Set-up**

The first step before completing an inspection of an element via Checklist is to make sure that the element that will be inspected contains all of the information and properties that the user wants to monitor. The asset that will be used for the purpose of this exercise is the ceramic tile as these are the heart and soul of the decorations of the structure. The product allows inserting information and properties through its Standard Properties, but the author wanted to personalize the data management and hence fixated on Custom Properties and their role on the project. The Custom Properties the author decided to implement for this ceramic tile are:

- Dropdown for Testing of Material Required
- Checkbox for Material Data Sheet
- Checkbox for Material Execution Data Sheet
These Custom Properties seemed to be sufficient to meet the goals set by the author in terms of data within the ceramic tile asset. The testing of material dropdown was important because this would demonstrate whether the support structure under the ceramic tiles had been experimented on. Another example would be the anti-graffiti liquid that is placed over these to ensure durability. The checkboxes symbolized whether or not the documentation for the asset was complete and uploaded in the cloud. The blank spaces were just a secondary verification method so that both the material and supplier information was attached to every equipment visible in the 3D model. The last checkbox represented whether or not the asset was visible on-site. Figure 4-26 displays the Custom Properties explained by the author and uploaded onto the BIM 360 interface.

Another vital feature was the formation of Statuses to monitor the progress and sequence of the assets throughout the construction stage. These Statuses would be modified to represent what was perceived during the on-site visits. In the case of the ceramic tile, the following Statuses were inserted that were coherent with the element:

- Acopio (Material Collection)
- Acceptat (Accepted)
- Installat (Installed)
- Connectat (Connected)
- Aprovat (Approved)

Checklist Set-up
The second step before applying a Checklist on-site was to configure it to meet the necessities imposed by the client. The Excel template mentioned in the beginning of the section compiles the information required to conduct a decent execution, but the software enables the user to create any further property or characteristic. In the case of the ceramic tile, the author determined that every checklist conducted on this element had to include both the signature of the General Contractor and the Construction Management firm to establish cogency.
and the outcomes will be abridged. Once again, the process will be detailed for the ceramic tile cited in the previous subsections.

The author decided to conduct an on-site visit to the station to determine whether the installation of the ceramic tiling was correct. The author had already configured and uploaded a Checklist to the ceramic tile elements so any inspections would be automatically attached and linked to the assets. As the author is conducting the inspection in his iPad, he notices that there are a couple of bumps and twists in the metallic support system holding the ceramic tile and hence select the Fail button for the line item on the checklist as seen in Figure 4-27. The Fail button had been configured so that it automatically creates an Issue, sort of like a trigger.

![Figure 4-27: Line-item fail for ceramic tile Checklist (Author)](image)

The author then continues by complimenting all the required information for the Issue. The information inserted in the Issue will be profoundly explained in the following section. The author then returns to the Checklist and continues inspecting the element while making all the appropriate photographs relating to the line items being confirmed. Figure 4-28 is a picture of the author conducting the inspection so that the reader can appreciate the means by which the dissertation paper was piloted. Figure 4-29 displays the images taken during the completion of the Checklist and the way the product stores the data specifically for the asset.
Figure 4-28: Author executing Checklist on ceramic tile (Author)

Figure 4-29: Photographs from Checklist on ceramic tile (Author)
4.5.6 Issues

The Issues module embodies the heart and soul of this dissertation paper because it is where the boundaries are limitless, and the user is invited to assert ingenuity and pair it with construction knowledge. Before jumping into the successful applications, it must be said that during the experimentation period many other smaller trials (like the ones presented below) failed to deliver any real utility.

Issues, as understood by BIM 360, are any incident, problem, mistake that takes place during the construction phase of the project. The first tab within the Issues module is Issue Types. These Types are meant to be reworded or reshaped to fit the needs of a project but are always thought of as a kind of conflict that arose. The author realized that every issue within a project can carry a heavy load of information coming in different shapes and sizes. Issues contain data in the format of: written details, attachments that range from PDF, Word, and many other standard format files, user comments, ability to be placed as a pin in a specific 2D drawing and even in the 3D model. These characteristics of the Issue opens the floodgates since the author realized that any issue could be used to symbolize something that really is not regarded as a problem, but any event taking place on-site with the capability to pinpoint its exact location and link documentation to it. Figure 4-30 illustrates the standard details that BIM 360 Field offers for which the user can then document information inside the Issue. The lock on the left hand-side means that these properties are mandatory for any Issue being created or the software will not be able to distinguish between various.

![Table of Issue Types](image)

Figure 4-30: Standards properties for Issues in BIM 360 Field

(Author)
**Issue Types**
The first step consisted on creating Issue Types that drifted from what BIM 360 Field considered as a stereotypical issue. It is noteworthy to remind the user that Issues are meant to be created via a failed line inspection of a checklist. Further on when the module Checklists is explained, the user will be guided through this process, but for now it is fundamental to understand that Checklists are the main generators of Issues in the BIM 360 Field platform. Whenever an inspection is conducted, an answer that does not comply with the standards and regulations set by the Checklist creator will trigger the generation of an Issue. The author brainstormed and came out with the following Issue Types:

- **Sonometrías (Sound Pressure Level Measurements)**
  - Monthly measurement of the sound pressure level required by the client
- **Assajos (Material Testing and Analysis)**
  - Testing of materials performed by either the General Contractor or the Construction Management firm
- **Testigos (Plaster tell-tales)**
  - The client set as compulsory the placement of plaster tell-tales in some cracks in the slurry walls to understand its behavior
- **Non-Conformities**
  - Issues that the Construction Management’s interdisciplinary teams decided that required a more stringent monitoring and control

**Custom Properties**
The second step of the process was to create custom properties that could match the requirements of the newly created Issue Types. These Issue Types vary so much from one another that the author wanted to test the flexibility of the product and conclude whether or not the applications were successful. These custom properties will be featured within the subsections of the Issue Types so that for each there is backup and reasoning behind proceeding in such way. Custom properties may be seen as the set of characteristics that pushed the individual Issue Type applications from “application was possible” to “application is possible and reaps benefits”. The statistical benefits of these applications will be presented in the latter section of analysis and key performance indicators.

**Root Causes**
Root Cause categories is another one of these features that Autodesk BIM 360 Field allows the users to toy with. The Root Cause categories are meant to be filled based on the firm’s experience and type of project. These root causes play an important role when discussing Issue Type statistics. The root causes are created so that whenever an Issue develops, the software allows the user to filter by this root cause and also offers the ability to generate visual charts using simple statistics such as which root causes appear to dominate the project scene. In the case of the L9 Foc Cisell Station Project, these Root Causes were arranged to grasp the major project disciplines of Architectural, Heavy Engineering, Quality and MEP. These categories match with those utilized by the Construction Management firm whenever a non-conformity is opened. Beneath each of these categories, the following standard root causes were established:

- Puesta en Obra (Set in Place)
- Documentación (Documentation)
- Producción (Manufacturing)

Furthermore, some discipline specific Root Causes were created as were the ones of equipment connection for MEP, lack of attention and cleanliness for Quality.
Given the fact that Root Causes are taken into account whenever the product calculates Issue Types statistics, the author had to figure out how to differentiate a Documentation Root Cause due to Architecture than one from MEP and so on. The way the author mitigated this issue was to add the acronyms of each discipline at the end of the Root Cause in capital letters as displayed in Figure 4-31. The result was fantastic, the software provided reliable data that could be segregated by project discipline and this way the construction management could gain further insight behind the amount of issues produced. Later on, the user will understand why these differentiation reaps benefits when analyzing pie charts and other types of graphs BIM 360 Field generates.

![Root Causes as configured within BIM 360 Field (Author)]

**Issue Templates**
Lastly, the software permits companies to create Issue Templates so that iPad accessibility whilst on-site is more straight-forward. These Issue Templates influence the manner in which Issues are created, the author had previously explained that the product incentivizes users to spawn these Issues by means of Checklists, but these templates enable the user to create Issues as 2D and 3D Pins without having to fill all of the checkboxes required. The user navigates to the virtual location where the Issue took place and then chooses any of the previously configured Issue Templates as these can shorten the time it takes for him/her to perch it. Issue Templates act as shortcuts that the iPad user can utilize if it fits its needs. In the case of the Foc Cisell station, the author decided to configure various Templates to contrast how these could affect the employing of the tablet on-site. The Issue Templates’ impact and analysis will be presented inside the individual sections concerning each of the Issue Types.

**Sonometrías (Sound Pressure Level Measurements)**

**Pre-application**
The sound pressure level measurements were the first big creative idea the author had in relation to the creative use of Issue Types. The author is required to make monthly visits with the General Contractor and measure how much noise is being produced by the construction project. The device used for these measurements is a highly calibrated sound level meter.
property of the GC. The measurements are taken at a determined location based on criteria such as exposure levels, impact on the neighborhood, works that produce the most noise, between other factors. Whenever the measurements are being performed, the GC carries a 2D birds-eye view drawing of the station that displays the measurement locations. Some sound level measurements are impacted by outside factors such as loud vehicle revving of engine, ambulance swinging by, or even incoming street shouts. The user must remember that the site is located at a corner and that the Passeig de la Zona Franca Street is a very busy corridor connecting the Port of Barcelona and ZAL (Zona Activitats Logístiques) with many trailer trucks ramping up and down. To account for these outside interactions, hand-written notes are taken by the GC to reason the high sound level calculated by the device. Once all of the measurements are taken, the author signs the 2D drawing to establish the validity of the procedure. Figure 4-32 represents a typical Sound Pressure Level Measurement performed for the project, this way the user can visually appreciate it the explanation written above.

The author then realized that this paper and pencil process could be digitalized and optimized by utilizing BIM 360 Field. The idea was first bounced with the Autodesk support personnel and they were dubious of the application of a non-issue as a type of issue in the software. The Issue Type for these measurements was created and tested the following month and standardized to set a standard of way of executing these on BIM 360 Field.
**Application**

The sound pressure level measurements seemed like a logical application as it’s a rudimentary procedure that shrieks digitalization all over it. The author brainstormed on the best manner to perform these measurements as Issue Types and what features and characteristics distinguished these from the others. The very first step was to ensure 2D drawing were loaded in the correct folder structure within the BIM 360 Field Library. These documents had to include the correct locations so that the 2D pins could be successfully adhered. Once this verification was made, the second step was to implant custom properties since these would allow for the measurement to prove itself as practical. The author recognized that an important factor behind the measurements was the fact that these were all backed-up by the Construction Management firm. The client has showed time and time again that they are extremely attentive with these smaller details. The author thought that a good approach to resolve these concerns was to create property that would display which responsible person from the Construction Management firm was present for the measurements. This Custom Property would always present itself whenever an Issue Type “Sonometrias” is opened.

The next step was to standardize the collection of information by the means of the tablet. The author ran several trials and tests to figure out which worked for him best but concluded that the best templates were those that had to be modified the least ones opened. Since the sound pressure level measurements are to be realized under two different conditions, with and without workers on-site, the templates represented these two scenarios.

The author had to shape the final details before visiting the station and conducting the measurements. Once the pin is attached to the 2D drawing, the manner in which the data would be stored had to be determined. The author decided that the title of the issue should be the quantitative measurement whilst the comments should include important information such as the exact time in which the measurement was performed. The company responsible for these measurements is UTEL9LL as they are the General Contractors and owners of the sound level meter.

The sound pressure level measurements are performed and the author attempts to collect all of the data on the iPad. The author followed the exact same procedure as the GC when taking all of the values of the measurements and recorded them as 2D pins in the specific drawing. The results are presented in Figure 4-33, the drawing to the left represents the pins for the sound pressure level measurements without workers, the with workers conditions is depicted on the right-most picture.

The author created a sound pressure meter using Arduino Uno and decided as a fun experiment to see how close the measurements could be when comparing to the certified device. This experiment was assigned for another course, but the author jumped at the idea and took advantage of it (Annex 3).
The author has to fill in the checkboxes while capturing all the data. These checkboxes display and require the input of the standard properties BIM 360 Field offers as well as any of the Custom Properties created for the specific project. Figure 4-34 is a set of screenshots that show the information that has to be set within each sound pressure level measurement. Attachments are only used for this Issue Type if it merits an extraordinary situation that differs from the average. The Root Cause category is left blank as these directly affect the project statistics and should not be confused with real project issues. The author uses real to stress the fact that even though an Issue Type for sound pressure level measurements was created, these are not issues that require a solution. Whenever a Root Cause is inscribed into an issue, this Root Cause will be visualized in the plots and graphs generated by BIM 360 Field, degrading the value of information portrayed by these diagrams. This case required special attention since the employment of these measurements as issues invoked the creation of 18 issues which could potentially derange the diagrams and display a diluted version of what is really important for the project. The diagrams encompass filtering methods to avoid these statistical mistakes, but that status of an issue proved to be the most rigid characteristic of an issue. The author opted on setting all the sound pressure level measurements as Work Completed as it was the closest match (Draft, Open, Work Completed, Ready to Inspect, Not Approved, In Dispute, Closed, Void). Each one of these statuses is linked with the 2D and 3D Pin’s color but cannot be modified in any way or form.
Once the measurements had been executed on-site, the author returned to its office and synchronized the information gathered into the cloud. The style in which the product presents the information is shown in Figure 4-35. The measurements are listed and contain the same material as what was inserted in the tablet, including the exact point where the measurement was taken (Figure 4-36). This figure outlines the importance of data accessibility by different means and interfaces (iPad and web-browser).

Figure 4-34: Sound Pressure Level Measurement as seen on iPad (Author)

Figure 4-35: Sound Pressure Level Measurements listed on the web-browser (Author)
Reports for the sound pressure level measurements worked surprisingly well and caught the author off-guard on the capabilities these could have on the digitization process. The template used for these measurements was the one of Issue List. The Issue List template permits the 2D drawing to be displayed at the beginning of the document and then list out all the individual pins by number. The author had to conduct some configurations to achieve this operation, but the essence of the matter is that it can be done and the results are outstanding. Figure 4-37 is an example of this kind of report created for the sound pressure level measurements performed during the month of March. The first image contains the pins and numbers then according to the order in which they were created, the second image is the list that conveys all the data behind the numbered 2D pins.
Figure 4-37: Issue List Report created for the March Sound Pressure Level Measurements (Author)

Fernán Vargas Renzi
**Pre-application**

The testing of materials for a construction management firm on a project with the scale and magnitude like the one of the L9 is crucial to ensure the client that the construction phase is under control. The QA/QC discipline should be aware of the construction processes so that they can schedule weekly testing of materials and systems being placed on the structure. The author’s involvement in this area is that he is responsible for these tests and confirming the results before the General Contractor can jump onto the next task in their planning. The General Contractor is required to deliver every Friday a three-week planning which involves the systems and elements being placed and/or constructed along with any tests that will be performed for these. The construction management firm then examines whether a test requires comparison tests. In the case of Foc Cisell station, the firm’s laboratory has been the same since the reactivation of the project so the communication channels are ones of trust and ease in scheduling and receiving of reports. The author normally communicates the laboratory two days in advance to make sure that the personnel is available and fully-equipped for the comparison test. Documentation may be sent before-hand such as drawings of the structure, material sheets, and even the specific testing methods.

The author acknowledged that the traceability of these tests carried an important message to the client of “staying on top of things” and good organizational practices. Normally these tests would be performed and stored in the company’s server in a structured format that would permit any user to find the documents when needed, but the author wanted to take it to the next level. The author believed that in the spirit of BIM, it would be a success if these documents would be attached to elements and specific locations within a 2D drawing and 3D model. The best method to achieve this goal was to create an Issue Type that comprised the tests performed by both the General Contractor as well as the Construction Management firm. The author is responsible of updating an Excel sheet that contains all these tests with hyperlinks that further shortens the time spent searching for the documentation. Table 4-2 displays the typical way in which these tests were stored within the server as well as the Excel sheet mentioned previously. Figure 4-38 shows the route that the users had to access in order to store the testing of materials.
### Table 4-2: Folder structure and registry of documentation for Testing of Materials and Systems (Author)

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#### Application

The implementation of the testing of materials seemed correlate in some ways with the sound pressure level measurements described previously as the objectives oscillated around the same idea of locating the exact positions where the tests took place. The author believed that it could be beneficial for both the pilot project as well as proving the practicability of BIM on more detailed manners than attaching information to 3D elements. An Issue Type was created to account for these testing of materials and then some Custom Properties had to be invented for the experiment to have greater validity. The Custom Properties deemed necessary where the following:

- Laboratory (referring to which Laboratory executed the tests)
- Person from the CM firm that attended the in-situ testing
- Person from the CM firm responsible for the test
  - The highest ranked person from every discipline (Architectural, MEP, Quality, Heavy Engineering)

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Fernán Vargas Renzi
These Custom Properties complimented the application perfectly as these were strings of information that could swing the balance towards a fruitful application. The author reminds the audience that the very first step always revolves the verification that the 2D drawing were loaded in the correct folder structure within the BIM 360 Field Library and linked to the correct locations so that the 2D pins could be successfully implanted. Referring back to the Custom Properties, the Laboratory dropdown was added so that whoever was navigating the 2D drawings could distinguish who performed the testing of the materials. The person in attendance was also an important factor as it is easier to trace back results (both positive and negative) by knowing who witnessed the execution of it. Normally the persons in attendance included the author and two other field engineers and this is why a dropdown menu was also designed for this category. Furthermore, the responsible for the test proved to be a significant detail as the standard procedure of acceptance of these tests states that the responsible of the discipline is to receive whichever tests belong to his/her discipline and accept or veto it.

Repeating what was written for the sound pressure level measurements, the next step was to standardize the collection of information by the means of the tablet. The author conducted experimentation off-field and on-site to determine which were most efficient. The templates for this case remained within the realm of the sound pressure level measurements as the author differentiated two different situations, tests performed by the General Contractors and those by the Construction Management firm.

The last few details had to be shaped before attempting to implement the Issue Type on-site. Once the pin is attached to the 2D drawing, the manner in which the data would be stored had to be determined. The author decided that the title of the issue should match the title of the report produced by the laboratory, the author knew most titles as the tests executed may repeat themselves many times as with the case of thickness of the fire-retardant mortar or weld inspections. The company responsible for these Issue Types depended on who conducted the test, if it was the General Contractor then UTEL9LL was selected while if it was a comparison test, the UTEL9T2. In contrast with the sound pressure level measurements that always took place at street level, the setting of the correct location for the tests was crucial as this enabled the 2D pinning on the right set of documents.

The Library set-up differed from the sound pressure level measurements as these were configured as a folder structure that only took the floor levels into account. The 2D pins were placed on the station’s floors and these pins would represent any test that was executed in this general area, regardless of the date. The approach for the sound pressure level measurements had to be conducted differently as the amount of Issues created per month was high and the location of these practically remained constant. The folder structure for the sound pressure level measurements was created by months to clean the displaying of the 2D pins.

Another disparity between the two Issue Types already described stemmed from the methodology behind the inputting of data onto the cloud. The sound pressure level measurements could be performed in-situ and no further enhancement had to be done. On the other hand, the pin placement of the testing of materials required a two-step process because of the lag time existing between the execution of the test and the acquiring of results. The author realized that the best way to mitigate this was to set the status for these pins without documentation as “In Dispute” as this changed the color of the pin and stood out. This was a simple method of comprehending which documentation was received and which was still pending. Figure 4-39 illustrated this color difference created by the author to discern the tests
whose documentation was complete and those who still required the uploading of the outcomes.

The author takes the iPad to the construction site knowing that a test will be performed on the steel structure that supports the elevators. The test that was scheduled is a verification of the conditions of the newly executed welds since the structure will be utilized to move material up and down before the installation of the elevators. The author creates a 2D pin at the location of the inspection and the results are presented in Figure 4-40. This illustration is the screen of the iPad as viewed by the author while performing the task at hand.

Figure 4-39: Use of Status and colors to differentiate Tests with and without documentation attached (Author)

Fernán Vargas Renzi
As explained previously on the Issue Type of sound pressure level measurements, the author is required to fill in the checkboxes while capturing all the data. These checkboxes display and require the input of the standard properties BIM 360 Field offers as well as any of the Custom Properties created for the Issue Type. Figure 4-41 is a set of screenshots that show the information that has to be set within the testing of materials 2D pin. Attachments are used for this Issue Type by taking photographs of the inspector performing the weld verifications. The Attachments within this Issue Type will also include the final report produced by the laboratory in charge of the inspection (in this case it was the General Contractor’s laboratory in charge of the testing of the welds) once this was available to the author. The Root Cause category is left blank as these directly affect the project statistics and should not be confused with real project issues as was the case with the sound pressure level measurements.

Figure 4-40: Inspection of welds on steel structure for Foc Cisell Station using iPad (Author)
A key distinction between both Issue Types presented so far (sound pressure level measurements and testing of materials) is the utilization of 3D Pins. The creation of 3D pins is within BIM 360 Field’s capabilities, but its usage is generally misunderstood. The author exchanged lengthy conversations with Autodesk personnel on the goal of these pins but none of the answers satisfied him. The biggest obstacle 3D pins deliver is the lack of connection with 2D pins. This means that the placement of a 3D pin cannot be interconnected with fellow 2D pins. This existing gap proved to be a challenge but allowed the blossoming of creative ideas to mitigate the hindrance. 3D pins can only be crafted and positioned in one way; 3D model navigation inside the iPad application and selecting the Pin button which immediately displays the Issue Templates for the project. Figure 4-42 visually describes what was explained above so that the reader grasps what the author is trying to express.
The author had to invent a methodology to create these 3D pins and not interfere with the overall functioning of the project. These 3D pins had to be managed carefully so that data would not be double-counted in the statistics displayed in the dashboard in the Project Overview tab. Another challenge posed was determining what information attached to the 2D pins versus 3D pins. The author decided that the information should portray all the documentation available regardless of the nature of the pin given that the Microsoft Azure cloud capacity was immense. The author defied the product and created a 2D pin and 3D pin for the exact same Issue while setting the standard that 3D pins were to carry the “3D” label at the end of every issue to distinguish between them (especially within the iPad). When a user opens an Issue on the web-browser, Issues with 2D pins will present a pin tab while the 3D pins do not share this characteristic. However, while on the iPad application, both 2D and 3D Issues show a pin icon next to their name, which could lead to confusion. Figure 4-43 depicts the labelling for both scenarios so that the reader visually understands the author’s explanation. Figure 4-44 demonstrates the distinction between 2D and 3D Issues by the display or lack thereof the pin tab. Lastly, Figure 4-45 is a screenshot that explains why confusion may arise if the user does not standardize the labelling of Issues as both 2D and 3D Issues display a colored pin.
Figure 4-43: The same test as created by 2D pin and 3D pin (Author)

Figure 4-44: Distinction between 2D Issue and 3D Issue lies on whether or not the pin tab appears within the Issue (Author)

Figure 4-45: 2D and 3D Issues as seen from iPad screen (Author)
Reports for the testing of material follow the same lines as the sound pressure level measurements. The template used for these measurements included both Issue List and Issue Details. The Issue List template permits the 2D drawing to be displayed at the beginning of the document and then list out all the individual pins by number. The author had to conduct some configurations to achieve this operation, but the essence of the matter is that it can be done and the results are outstanding. Figure 4-46 is an example of this kind of report created for the testing of materials executed. The first image contains the pins and numbers then according to the order in which they were created, the second image is the list that conveys all the data behind the numbered 2D pins. The reason why the author chose to select another typology of report was because the Issue List does not place a pin for the 3D Issues and they can get lost inside the report, the Issue Details report emphasizes the tests performed while not losing time with the decoration of a 2D drawing the pins. Figure 4-47 is an example of the Issue Details report generated by the author for the project.

Figure 4-46: Issue List Report created for Testing of Materials (Author)
Testigos (Plaster tell-tales)

Pre-application
The plaster tell-tales surged from the rising trepidations of the client and the desire to assure him that the construction management firm was under control. During one of the many interdisciplinary meetings, the client noted that one of its representatives had spotted cracks on the circling slurry walls of the station. The construction management firm demanded that the General Contractor had to examine the cracks and determine whether or not these had any structural implication. The General Contractor’s structural analysis team analyzed the cracks and wrote a technical memorandum explaining how these were not of structural importance but had to be monitored regardless. The construction management firm took the initiative to place plaster tell-tales on these fissures so that the QA/QC personnel could see if any of these cracks were expanding and required intervention. The author’s involvement in the subject derives from his direct responsibility of monitoring and controlling these cracks. The construction management firm chose some of the biggest cracks located in the slurry walls of Figure 4-47: Issue Details Report created for Testing of Materials (Author)
the emergency stairways (mountain side). The author is required to do monthly inspections on
the plaster tell-tales to see whether or not these have evolved.

The procedure consists of the author visiting the plaster tell-tales and inspecting them one by
one. The author is required to make photographs of the seal-like object and measure the width
of the opening of the plaster tell-tale (if any). This process is repeated for every one of them,
starting from the story level 0 through level -5 which is the location of the last plaster tell-tale.
The author then returns to the office and fills in the following Excel sheet for all 12 of them.
Table 4-3 displays an Excel sheet that corresponds to the plaster tell-tale #1. The author is also
responsible to update an existing Word document that contains the last photograph taken for
the plaster tell-tale and the number to match it with the Excel. Figure 4-48 displays the Word
document with plaster tell-tale #1 so that the reader understands the basis of the rudimentary
methodology behind the control undertaken. Annex 4 displays the entirety of the Word
document if the reader is interested in seeing the handful of plaster tell-tales.

Table 4-3: Excel used to control plaster tell-tales (Author)

<table>
<thead>
<tr>
<th>FECHA COMPROBACIÓN</th>
<th>APERTURA</th>
<th>ANCHO (MM)</th>
<th>RESPONSABLE INSPECCIÓN</th>
</tr>
</thead>
<tbody>
<tr>
<td>11/23/17</td>
<td>X</td>
<td>0 mm</td>
<td>Fernán Vargas</td>
</tr>
<tr>
<td>1/31/18</td>
<td>X</td>
<td>0 mm</td>
<td>Fernán Vargas</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
The author then fathomed that there ought to be a way to digitize and implement this process in BIM 360 Field, especially after the successes of the sound pressure level measurements and testing of materials. The idea was to somehow connect the images and the positioning of these plaster tell-tales so that the author conducting the inspections could have an easier time locating these objects. As a side note, regardless of the description of the positioning of the tell-tales, as construction has ramped up some of these have been buried behind conducts and cable trays. The author has to update his tables to account for this disappearing of tell-tales and in some cases, discovery of ones that used to be hidden behind temporary elements. The side note’s purpose is to describe that the activity is not as straight-forward as one may believe, finding these plaster tell-tales on wide spaces on a slurry wall requires patience and time. This growing frustration propelled the idea of creating an Issue Type to encompass tell-tales and place pins on their exact locations, both in 2D as well as in 3D.
Application

The application of the plaster tell-tales as an Issue Type coincided with some of the main goals described for sound pressure level measurements and testing of materials as the positioning of these as 2D pins was crucial for its success. The author believed that this implementation could be the most detailed-oriented of them all and it encompassed a topic that involved the least participants. An Issue Type was created to account for these plaster tell-tales and then some Custom Properties had to be generated to invigorate the process and substantiate the investing of time required by the author. Two Custom Properties were configured by the author for this Issue Type as these were utilized in the paper and pencil method and had to be accounted for. The first Custom Property asks whether or not the plaster tell-tale is visible or not, set-up as a dropdown menu. The second Custom Property mandates that the user conducting the verification digitally signs the Issues (2D pins). There was a bonus Custom Property that will be explained in later in the section to explain the cause behind its creation.

Re-stating what has been previously described in the other Issue Types, the next step was to standardize the collection of information by the means of the tablet. The author conducted experimentation off-field and on-site to determine which techniques were optimal. In the case of the plaster tell-tales several iterations were ran because the author was unsure how to set up the carpet structure. The Template for this Issue Type proved to be simpler since there are no clear variances between the plaster tell-tales, they serve the same purpose and were placed in a similar fashion. This Template was named Testigo (Plaster tell-tale) and facilitated the placing of pins while on-site by means of the iPad application.

The author has to brainstorm the work methodology and try to standardize it so that it could be easily repeated and eventually explained to other users. The procedure to set the 2D pin has been explained several times, but what is always transcendental is the way the data is stored within the Issue Types. The author decided that the title of the issue should match the numbering that was up till then used in both the Word and Excel documents. This approach minimized mistakes as the author already knew the plaster tell-tales by number and it made sense to keep it the way it was. The company responsible for these Issue Types was set as UTEL9T2 as it was the construction management firm’s responsibility to monitor these and alert other entities if the status quo was altered. Compared to the other Issue Types already explicated, the setting of the correct location for the plaster tell-tales resembled the testing of materials as the 2D pinning had to be executed in the correct 2D drawings. In the sound pressure level measurements and testing of materials scenarios, the information molded the basic pillar of the implementation and this varied with the plaster tell-tales as the location garnered an weight un-seen before.

The Library set-up strayed from the sound pressure level measurements as these were configured as a folder structure that only took the floor levels into account. These 2D drawings were derived from the excellent application results obtained from the testing of materials. The author realized that if the Issue generation rate is relatively low, one drawing can accommodate and position multiple pins while conveying the data effectively. The 2D pins were placed on the station’s floors without regard for the date of the inspection, the only criterium was whether the plaster tell-tale was enclosed in the 2D drawing. As mentioned in the sound pressure level measurement subsection, the pins for the measurements had to revolve around the date of their conception and this influenced the folder structure as it had to be configured by months to clean the insurmountable amount of 2D pins displayed in a single 2D drawing.
A unique obstacle confronted for these plaster tell-tales was discovered as the author was still setting-up the Library. The author recognized that some of the tell-tales were located on levels situated in between the main stories. These secondary levels are only appreciated whenever travelling through the emergency stairways and there are no 2D drawings associated to them so the author’s ability to locate the pins was hindered. The author had to overcome the challenge whilst designing a standard to account for these situations. The author opted to create a third Custom Property called Exact Location to undermine this problem and ensure that the user could find the tell-tale even if the pin could not specify the precise coordinates.

This methodology related to the input of information was closest to the sound pressure level measurements as the work was conducted in-situ without further enhancements required. The author determined that the status of the pins could be set as Work Completed as it correlated better with the line of work being performed by the user. Hopefully the audience remembers that Work Completed has been previously used for the sound pressure level measurements as well as the material tests with documentation.

Another special attribute for this Issue Type is the fact that the author decided that the mere fact that an inspection occurred, did not mandate the creation of a 2D pin. This strategy drastically varied from the ones explained for the other Issue Types as every bit of information was collected as an individual 2D pin. The author decided that every revision had to be solemnized in the Comments section. The user is obliged to set the inspection date and the software automatically displays the author of the comment. This methodology was implemented to understand if there was any way that revisions like these could be simplified and improved after all the lessons absorbed from the sound pressure level measurements and the testing of materials. Figure 4-49 displays the new methodology employed for this Issue Type.

The author tries the system out for the first now and visit the Foc Cisell station with his iPad. The author starts from atop the station and starts creating 2D pins whenever he encounters a plaster tell-tale. The author attempts to follow the same guidelines as when the process was executed without the iPad to capture the most miniscule of differences with respect to time and difficulty. Figure 4-50 displays the first 2D pin drawn by the author and the way it is inscribed into BIM 360 Field.
The author is required to fill all the blank spaces enclosed in the Issue while capturing all the data. These spaces demand information relating standard properties BIM 360 Field offers as well as any of the Custom Properties created for the Issue Type. Figure 4-51 is a set of screenshots that show the information that has to be set within the plaster tell-tale 2D pin. The only Attachments used for this Issue Type are the record of photographs inspector performing the appropriate verifications. The Root Cause category is left blank as these directly affect the project statistics and should not be confused with real project issues as was the case with the sound pressure level measurements.
This Issue Type also utilized 3D pins to successfully meet the author’s objectives. The methodology for a righteous utilization of the 3D pins had already been laid up for the testing of materials Issue Type so the author took advantage of the situation. To refresh the user’s memory, 3D pins can only be created while on 3D model navigation inside the iPad application and selecting the Pin button which immediately displays the Issue Templates for the project. Figure 4-52 serves as an explanation as the author’s approach for 3D pins and the plaster tell-tales.

Figure 4-51: Testing of Materials as seen on iPad (Author)

Figure 4-52: Plastic Tell-Tales #2 and #3 as seen on iPad using 3D Pins (Author)
The author re-used the previously established methodology to create these 3D pins and not interfere with the overall functioning of the project. These 3D pins had to be managed carefully so that data would not be double-counted in the statistics displayed in the dashboard in the Project Overview tab. The author decided that the information should portray all the documentation available regardless of the nature of the pin. The author defied the product and created a 2D pin and 3D pin for the exact same Issue while setting the standard that 3D pins were to carry the “3D” label at the end of every issue to distinguish between them (especially within the iPad). This labelling standard was invented for the Issue Type of testing of materials. If the reader wants more information regarding 3D pins, the author recommends the lecture of the previous Issue Type as the differences between 2D and 3D pins are analyzed.

One important divergence from the 3D pin methodology mentioned was the Status applied to the 3D pins compared to that of the 2D. The author realized the importance of the statistics displayed on the Project’s Overview dashboard and how these could be meddled with. The author decided that the creation of a 3D pin for an issue already represented by a 2D pin should not deviate the indicators and therefore these 3D pins should be assigned a Draft status. Table 4-4 illustrates the case by listing the plaster tell-tales for both 2D and 3D pins.

### Table 4-4: Issue Status for Plaster Tell-Tales in 2D and 3D (Author)

<table>
<thead>
<tr>
<th>ID</th>
<th>Description</th>
<th>Company</th>
<th>Status</th>
<th>Location Path</th>
</tr>
</thead>
<tbody>
<tr>
<td>000162</td>
<td>Testigo #1</td>
<td>UTEL9T2</td>
<td>Work Completed</td>
<td>Estació de Foc&gt;Planta -2</td>
</tr>
<tr>
<td>000163</td>
<td>Testigo #2</td>
<td>UTEL9T2</td>
<td>Work Completed</td>
<td>Estació de Foc&gt;Planta -3</td>
</tr>
<tr>
<td>000164</td>
<td>Testigo #3</td>
<td>UTEL9T2</td>
<td>Work Completed</td>
<td>Estació de Foc&gt;Planta -3</td>
</tr>
<tr>
<td>000165</td>
<td>Testigo #4</td>
<td>UTEL9T2</td>
<td>Work Completed</td>
<td>Estació de Foc&gt;Planta -4</td>
</tr>
<tr>
<td>000166</td>
<td>Testigo #5</td>
<td>UTEL9T2</td>
<td>Work Completed</td>
<td>Estació de Foc&gt;Planta -4</td>
</tr>
<tr>
<td>000167</td>
<td>Testigo #6</td>
<td>UTEL9T2</td>
<td>Work Completed</td>
<td>Estació de Foc&gt;Planta -5</td>
</tr>
<tr>
<td>000168</td>
<td>Testigo #7</td>
<td>UTEL9T2</td>
<td>Work Completed</td>
<td>Estació de Foc&gt;Planta -5</td>
</tr>
<tr>
<td>000169</td>
<td>Testigo #8</td>
<td>UTEL9T2</td>
<td>Work Completed</td>
<td>Estació de Foc&gt;Planta -5</td>
</tr>
<tr>
<td>000170</td>
<td>Testigo #9</td>
<td>UTEL9T2</td>
<td>Work Completed</td>
<td>Estació de Foc&gt;Planta -6</td>
</tr>
<tr>
<td>000171</td>
<td>Testigo #1 3D</td>
<td>UTEL9T2</td>
<td>Draft</td>
<td>Estació de Foc&gt;Planta -6</td>
</tr>
<tr>
<td>000172</td>
<td>Testigo #2 3D</td>
<td>UTEL9T2</td>
<td>Draft</td>
<td>Estació de Foc&gt;Planta -6</td>
</tr>
<tr>
<td>000173</td>
<td>Testigo #3 3D</td>
<td>UTEL9T2</td>
<td>Draft</td>
<td>Estació de Foc&gt;Planta -6</td>
</tr>
<tr>
<td>000174</td>
<td>Testigo #4 3D</td>
<td>UTEL9T2</td>
<td>Draft</td>
<td>Estació de Foc&gt;Planta -6</td>
</tr>
<tr>
<td>000175</td>
<td>Testigo #5 3D</td>
<td>UTEL9T2</td>
<td>Draft</td>
<td>Estació de Foc&gt;Planta -6</td>
</tr>
<tr>
<td>000176</td>
<td>Testigo #6 3D</td>
<td>UTEL9T2</td>
<td>Draft</td>
<td>Estació de Foc&gt;Planta -6</td>
</tr>
<tr>
<td>000177</td>
<td>Testigo #7 3D</td>
<td>UTEL9T2</td>
<td>Draft</td>
<td>Estació de Foc&gt;Planta -6</td>
</tr>
<tr>
<td>000178</td>
<td>Testigo #8 3D</td>
<td>UTEL9T2</td>
<td>Draft</td>
<td>Estació de Foc&gt;Planta -6</td>
</tr>
<tr>
<td>000179</td>
<td>Testigo #9 3D</td>
<td>UTEL9T2</td>
<td>Draft</td>
<td>Estació de Foc&gt;Planta -6</td>
</tr>
</tbody>
</table>

Reports for the plaster tell-tales did not vary from the previous two Issue Types presented. The template used for these measurements was focused on the Issue List template as it permits the 2D drawing to be displayed at the beginning of the document and then list out all the individual pins by number. Figure 4-53 is an example of this kind of report created for the inspection of the plaster tell-tales conducted by the author. The first image contains the pins and numbers then according to the order in which they were created, the second image is the list that conveys all the data behind the numbered 2D pins.
Figure 4-53: Issue List Report created for inspection of Plaster Tell-Tales (Author)

Fernán Vargas Renzi
Non Conformidades (Non-conformities)

Pre-application
Non-conformities may be the single leading influencer on the client’s opinion and sentiments towards the construction management firm. According to one of the top ranked engineers from the firm, these non-conformities define whether the quality of the construction phase is meeting the standards and norms set by the client. The author can testify that these documents reach the highest audience and the smallest of details are meticulously verified. Non-conformities are responsibility of the QA/QC discipline for which the author is responsible for and hence his involvement in this topic surpasses many of the other applications.

Non-conformities can be created for either heavy engineering, MEP, architectural and QA/QC imperfections so its monitoring and control entails active participation of all members in the construction management firm. The structure of this subsection follows the path of the other Issue Types but the current methodology used by the author to open, monitor and eventually close these non-conformities will be highlighted so the reader can glimpse at the importance of the application. This application conveys a profound message that not only implicates BIM 360 Field but the digitization of the data. The author’s bosses expect that the master Excel for non-conformities should be updated daily to make sure it is correct whenever the client demands it.

Non-conformities can be opened following two different workflows; one by means of the General Contractor or by the construction management firm. The requirements imposed to the General Contractor state that if the construction management firm opens a non-conformity, the GC is forced to open it as well. This workflow does not reciprocate as the construction management firm is not mandated to open a non-conformity when the GC does. Normally non-conformities are discovered whenever a construction management team goes on-site and discovers an issue that should be corrected, repaired or substituted. The causes of the non-conformities are widespread and can symbolize lack of documentation, work executed not according to the official 2D drawings, incorrect placement in-situ, and many other bases.

QA/QC meetings between the general contractor and construction management firm take place once a month and non-conformities are always the focal point. The GC is required to explain the status of the opened non-conformities and to inform if there are any new ones. Normally, given the good relationship between both entities, the QA/QC responsible of the GC and construction management firm are speaking every day to sustain and interchange information which emanates in the author being informed of a non-conformity opened by the GC within the day. These meeting are also important because the documentation relating these NC’s can be signed by both parties to make official openings or closures.

The general contractor generates its own tables regarding non-conformities and these are attached in the QA/QC report the first week of every month. The construction management firm also embellishes its own table to double check the information displayed in the report. The author is solely responsible to build and actualize the Excel of these non-conformities. Table 4-5 displays the Excel the author updates in a daily fashion for optimal control of the non-conformities.
Table 4-5: Excel used to control Non-conformities (Author)

<table>
<thead>
<tr>
<th>ACC.</th>
<th>CODE</th>
<th>DESC.</th>
<th>FECH</th>
<th>COMENTARIOS</th>
<th>FECH. DE FIN</th>
<th>FINALIZ.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1103</td>
<td>103</td>
<td>Excel used to control Non-conformities (Author)</td>
<td>12/01/2017</td>
<td>-</td>
<td>12/01/2017</td>
<td>CERRADA</td>
</tr>
<tr>
<td>1104</td>
<td>104</td>
<td>Excel used to control Non-conformities (Author)</td>
<td>12/01/2017</td>
<td>-</td>
<td>12/01/2017</td>
<td>CERRADA</td>
</tr>
<tr>
<td>1105</td>
<td>105</td>
<td>Excel used to control Non-conformities (Author)</td>
<td>12/01/2017</td>
<td>-</td>
<td>12/01/2017</td>
<td>CERRADA</td>
</tr>
<tr>
<td>1106</td>
<td>106</td>
<td>Excel used to control Non-conformities (Author)</td>
<td>12/01/2017</td>
<td>-</td>
<td>12/01/2017</td>
<td>CERRADA</td>
</tr>
</tbody>
</table>

Fernán Vargas Renzi
The figure above utilizes a color scale to improve the conveyance of information. The rows that are colored in a light vanilla color represent any non-conformity that has suffered changes with respect to last month, hence these are the ones to look at when viewing the document. The darker yellow rows stand for the non-conformities that have been closed during the current month and the last column is either shaded red or green depending if the General Contractor met the deadline set by the construction management firm when the non-conformity was first opened. The author created a couple of simple graphs so that the client could visually understand the situation of the non-conformities the last couple of months. Figure 4-54 depicts these graphs, so the reader sees that the author has tried to implement and enhance most of the work that he is responsible for. The pie chart of the left represents the last 3 months while the diagram on the right the calendar year.

The first manner by which non-conformities may be opened is whenever the General Contractor figures out that they have erred and decide to document it. It is important to note that the construction management firm encourages the GC to open NC’s as this is the proof that the QA/QC is under control and top of things. Mistakes are an essential part of the construction phase, the mitigation of these is what separates competitive companies from sloppier ones. If the GC opens a non-conformity, the QA/QC opens a non-conformity templates that states the issue and important details such as the responsible for its correction, the expected date of its resolution, what discipline is involved, and much more information. This template must be signed by the direct responsible for its resolution and also by the QA/QC responsible, these two may be the same as in the case of the figure presented below. Once these two signatures have been gathered, the template is sent to the author who is the QA/QC responsible and he verifies that the information makes sense and the formatting. The author may either return for corrections or distribute within the construction management firm depending on the typology of the non-conformity. If the non-conformity related to heavy engineering or quality, the author is allowed to make a determination of whether or not the construction firm will be opening the issue, whilst if it belong to MEP or architecture the template is relocated. A typical non-conformity template is shown in Figure 4-55 so that the reader can grasp what the author has written. This non-conformity showcases an example of a non-conformity opened by the General Contractor after conducting a regular inspection.

Figure 4-54: Pie Charts displaying closure of Non-conformities (Author)
If the construction management firm decides that the non-conformity carries sufficient significance to open, then the responsible for each discipline fills in the non-conformity template specific for the construction management firm. This template differs from the GC’s because it only required the signature of its author to be official. The person responsible for the template then communicates the author that the template is ready, and the author checks to see all the details are valid and then sends it to the GC so that they can save it in their server. The official template utilized by the author’s firm is presented in Figure 4-56, the reader should notice that it is not the same non-conformity as the presented previously for the GC but serves as an illustrative description of the task at hand. Both non-conformity templates require attachments so that other participants understand the issue at hand. These attachments range from straightforward 2D drawings of the location of the non-conformity or even photographs that capture the mistake that must be dealt with.
The GC is also obliged to immediately open a corrective action template explaining what the expected solution is. This expected solution is not definite and traditionally strays from the truth as the GC does not possess all the information required to execute a solution, but it is an approach that forces the GC to think about potential solutions before even confronting the issue.

The next sequential step consists of closing a non-conformity and this can also follow two different paths. The closing of a non-conformity means that the General Contractor have met all the objectives written in the non-conformity template. Usually the approach for the closure of non-conformities relays on the GC performing a correction and notifying the construction management firm that the mistake has been absolved. The author’s role here is informing the team and making sure that an inspection of the correction takes place as to be sure that it can be shut. Once these corroborations are undergone, the General Contractor formulates the corrective action template with the actual corrections performed instead of the previously confected proposal. This corrective action template should also contain attachment in form of testing of materials, photographs, technical memorandum explaining that the on-site execution is structurally stable, and so on. This corrective action requires the signature of three people: the responsible for its correction of the GC, the QA/QC responsible for the GC and lastly the responsible for the construction management firm. Figure 4-57 displays a corrective action template already signed by all the person involved and hence officially closed and archived. This figure encases the case of a steel structure that failed to meet the weld inspections conducted by both laboratories for the GC and construction management firm. The General Contractor was forced to make the appropriate modifications and schedule inspections to ensure that the welds that had failed in the initial inspections were now well-formed.

Figure 4-56: Non-conformity template for the General Contractor (Author)
The construction management firm then types their own corrective action template as to match the one formed by the General Contractor. The template should include attachments that validate the closing of the non-conformity and requires the signature of the GC. The management of these templates is handled by the author of this dissertation paper and he then updates the Excel table previously presented. A non-conformity is closed once the author possesses all four templates with the appropriate signatures. An example of this corrective action template is presented in Figure 4-58 so that the reader can visually comprehend the differences between all four templates. The example portrayed in the figure stands for the same non-conformity regarding incorrect welds in the steel structure.
The author heaved for the opportunity to digitize this process or at least boost it. Non-conformities are the essence of QA/QC, so the author knew that the objectives set for this Issue Type could potentially carry massive consequences in the management of these non-conformities. The author fathomed that this implantation could include the basic capabilities of the software such as positioning the non-conformities with both 2D and 3D pins but that everything created within this Issue Type had to be well-thought and structured as this category involved the active contribution of other members. The other Issue Types mentioned before were inventions conducted by the author as a way of expressing accessibility and ease-of-use in day to day processes. This category symbolizes much more, the Issue Type linked to non-conformities could pave the way of operating these types of issues. The author focused his attention on documentation, location and automation of the processes that constitute opening and closing a non-conformity.
**Application**

The application of non-conformities was the author’s most important feat within the implementation of Issue Types in BIM 360 Field. Non-conformities are the only type of Issue Type that align better with Autodesk’s design of the software. Non-conformities are a type of issue, so the author did not have to start a methodology from scratch but instead test the methodologies the Autodesk personnel recommended. Once the established methodology was put to trial, the author enhanced it to suit the necessities of the L9 Foc Cisell Project which proved to be the most important part of this subsection.

The objectives from this application revolved around the idea of locating the exact positioning of these issues and ensuring that the uploaded and attached information was up-to-date. The goals set in this application were vital if the project as a whole wanted to be successful as non-conformities were put in a pedestal and wrought to be the milestone that determined whether the pilot project was beneficial. The smaller details within the Issue Type played a larger role as the status of the non-conformities or the responsible for its closure ascertained more importance than for example the company that executed a testing of material. An Issue Type was created to account for these non-conformities and then some Custom Properties had to be invented for the experiment to have greater validity. The Custom Properties deemed necessary where the following:

- Code General Contractor
  - Code utilized by the GC to name the non-conformity
- Signature General Contractor
- Signature Construction Management firm
- Non-conformity closed before set deadline
  - Important aspect the client mandated to be established for every non-conformity
- Reception of the General Contractor’s NC template
  - Date when the NC template was received
- Reception of the General Contractor’s AC template
  - Date when the AC template was received

These Custom Properties were required for a correct application of the Issue Type of non-conformities as these were the details that were already being used before the BIM 360 Field implementation. The client was pleased with the current workflows so a digitization process had to include these to let them see that the author was attempting to create a newer concept built with stable and broad foundations. The author takes a moment to remind the reader that the first step always entails the verification that the 2D drawing were loaded in the correct folder structure within the BIM 360 Field Library and linked to the correct locations so that the 2D pins could be successfully implanted. Referring back to the Custom Properties, the Code General Contractor property was added because the code from both GC and CM firms defer from one another and the amount of waste and confusion created while communicating these through emails surpassed what the reader may be imagining. The author believes that problem can be mitigated by this simple blank space containing the code utilized by the GC so that both are present within every Issue. The signatures are also used for non-conformities as these are an interesting feature that validates the process and symbolizes that both parties are informed of the Issue and its situation. The deadline property was also an important characteristic that had be included as the client mandated that they wanted to keep track of the expected time of closure versus the actual time it took to close it. Figure 4-54 in the pre-application section presented the graphs the author had created to accommodate the client’s wishes. The Custom Properties that deal with the reception date were also configured to keep a tighter control on the documentation side of the non-conformities. As was mentioned in the previous subsection,
the workflows for these templates is a bit chaotic and establishing these features allows the
author to acknowledge when the official templates (with signatures and corrections) have been
stored within the Construction Management firm’s server.

Re-stating what had been said for the previous Issue Types, the next step was to standardize
the collection of information by the means of the tablet. The author conducted experimentation
off-field and on-site to determine the methodology proposed by the Autodesk personnel and
then contrast it with what he deemed to be the best way to perform the implantation.

Root Causes finally came into the picture as these were designed to be utilized strictly for
Issues that were closely-related to a problem, mistake, conflict present during the construction
phase. The author has already explained how the configuring of Root Causes on Issue Types
that do not fit the “Issue” category should be avoided so that the statistics generated by the
software stays truth and only includes real conflicts. Root Causes were invented while thinking
about the non-conformities that ordinarily emerge during the construction stage by discipline.

The templates for this case remained within the realm of several of the other Issue Types
already presented, the non-conformities were categorized according to the entity responsible
for its detection and opening which in this case could be either the General Contractor or the
Construction Management firm. It should be noted that whenever a non-conformity opened by
the GC was formerly opened by the CM firm, the Issue Type would then be designated as a
non-conformity whose closure depended on the construction management firm.

The last few details had to be shaped before attempting to implement the Issue Type on-site.
Once the pin is attached to the 2D drawing, the manner in which the data would be stored had
to be determined even if the methodology implemented was grounded on the basics of the
product’s design team. The author decided that the title of the issue should match code
nominated by either the GC or CM firm so that its identifying was straight-forward. These
codes were to match those of the Excel that managed non-conformities, this procedure also
minimized mistakes as the author knows non-conformities by its codes as he is dealing with
these on a daily manner. The company responsible for these Issue Types was set as UTEL9LL
(GC) if the non-conformity was one that the CM firm deemed minor and not worth opening
whilst it was set as UTEL9T2 if opened by the author’s company. The Status for the Issue was
fundamental as this had to reflect on the actual status of the non-conformity on the project. The
procedure to close non-conformities was explained earlier but it failed to mention the way the
author closed them on BIM 360 Field. The date when the Status is changed cannot be modified
which meant that the author had to close the non-conformities on the iPad the same day that it
was closed on the project. The hindrance to this methodology was that some non-conformities
are closed on the monthly QA/QC meetings between the GC and the CM firm, but the official
documentation may not be prepared or received by the author until the latter days. The
determination was that the date that the non-conformity was agreed to be closed, was the one
displayed on BIM 360 Field even if the documentation was sent a couple of days later.
Compared to the other Issue Types already expounded, the setting of the correct location for
the non-conformities resembled the other Issue Types as these had to be set in the correct 2D
drawings. A key feature of the non-conformities was that the comments tab within the Issue’s
window was to correspond the exact description scripted in the non-conformities Excel. Figure
4-59 displays an example of a non-conformity whose title symbolizes the code and for
accessibility and ease of use its description is portrayed in the comments tab. This step benefits
users whose jobs does not require their awareness of the specific codification used for non-
conformities and then can realize if the Issue matches what they were looking for.

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The Library set-up strayed from any of the other Issue Types as non-conformities were directly linked to the folder structure containing the official 2D drawings. For the other Issue Types, different folder structures were generated to account for them and isolate the noise these produce in the overall functioning of the project. As non-conformities have a huge influence on the implementation, these Issue Types were directly set on the original folder structure for the 2D drawings. It should also be stated that the application of non-conformities was the first one and hence the author was unaware of the nature of the problems that heathen from using a 2D drawing for multiple purposes. These official 2D drawings are configured by floors but the author also deliberately created sub-locations for these drawings so that the individual rooms and areas were zoomed in when selected. An example of this is illustrated in Figure 4-60, non-conformities could be located as specific as individual chambers inside the floor. This was a game-changer but also proved to involve a non-intended difficulty factor as the non-conformities located in specific rooms within a story could not be visualized in the table application when electing to see the Issues located in the floor, the user had to select the exact location to visualize the issues.

As a side-note, as the author was creating these methodologies explained throughout the section, his first reaction was to document in a journal his experiences as he was working with the software. These problems, benefits, shortcuts, would then be used as a general template for the approach used in the dissertation paper (Annex 5).
The general approach for the Library structure of these non-conformities was that it would be better to allocate all the non-conformities in the same 2D drawing to grasp the amount of them present by different areas. The data regarding the date and other approaches mentioned for the previous Issue Types would also be configured within the Issue so it did not influence the author’s methodology of creating a folder structure that incentivized the perceiving of non-conformities and withdraw conclusions from these pins.

This Issue Type closely followed the path set for the testing of materials in relation to the input and collection of information both on-site and on the office. Non-conformities could be created during an on-site visit by the means of the iPad application and both 2D and 3D pins could be placed while standing in front of the problem but also required some development when returning to office. Most of the office work would be focused on the documentation side of the non-conformities as data would have to be attached and details had to be modified once the GC compiled and sent their templates.

The author’s first step was to update the BIM 360 Field information with the non-conformities that were currently open for the Foc Cisell station. To conduct these apprises, he must look
back at the Excel and try to locate the non-conformities in both 2D drawings and the 3D model. This process proved to be harder than what was hypothesized as the author had paved the way for the addition of non-conformities from their conception and not the summarizing of older non-conformities whose processes echoed those of the older method. The author is required to fill all the blank spaces enclosed in the Issue while finding all of the data. These spaces demand information relating standard properties BIM 360 Field offers as well as any of the Custom Properties created for the Issue Type. Figure 4-61 is a set of screenshots that show the information that has to be set within a non-conformity pin. The Attachments used for this Issue Type are the record of photographs obtained from the person detecting the non-conformity as well as the official templates for both the General Contractor and Construction Management firm for non-conformities as well as their respective corrective actions.

Figure 4-61: Non-Conformities as seen on iPad (Author)
This Issue Type also utilized 3D pins to successfully meet the author’s objectives and try to persuade the client that this implementation brings more to the table than the older method. The methodology for a correct utilization of the 3D pins had already been laid up for the testing of materials Issue Type as well as the plaster tell-tales so the author decided to try this methodology out on the most important Issue Type of non-conformities. To refresh the user’s memory, 3D pins can only be created while on 3D model navigation inside the iPad application and selecting the Pin button which immediately displays the Issue Templates for the project. Figure 4-62 serves as an explanation as the author’s approach for 3D pins and the non-conformities.

The author re-used the previously established methodology to create these 3D pins and not interfere with the overall functioning of the project. These 3D pins had to be applied meticulously so that data would not be double-counted in the statistics displayed in the dashboard in the Project Overview tab. The author decided that the information should represent all the documentation available regardless of the nature of the pin. The author defied the product and created a 2D pin and 3D pin for the exact same Issue while setting the standard that 3D pins were to carry the “3D” label at the end of every issue to distinguish between them (especially within the iPad). This is the exact same method as described for previous Issue Types and its development is elucidated in the testing of materials subsection.

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As the reader may remember from the other Issue Types, a difference between the 2D and 3D pin is the Status applied to the 3D pins compared to that of the 2D. The author realized the importance of the statistics displayed on the Project’s Overview dashboard and how these could be meddled with. The author decided that the creation of a 3D pin for an issue already represented by a 2D pin should not deviate the indicators and therefore these 3D pins should be assigned a Draft status which was the same methodology as the other Issue Types. Table 4-6 illustrates the case by listing the non-conformities for both 2D and 3D pins. Also noteworthy is the fact that the 3D pins are not endowed with a Root Cause to avoid the double-entry of information or statistics in this case.

<table>
<thead>
<tr>
<th>ID</th>
<th>Description</th>
<th>Status</th>
<th>Type</th>
<th>Root cause</th>
</tr>
</thead>
<tbody>
<tr>
<td>00010</td>
<td>NC-EZF-FCS-003</td>
<td>Closed</td>
<td>No conformidades</td>
<td>Falta de atención QUALITAT</td>
</tr>
<tr>
<td>00012</td>
<td>NC-MA-EZF-FCI-001</td>
<td>Closed</td>
<td>No conformidades</td>
<td>Documentación QUALITAT</td>
</tr>
<tr>
<td>00005</td>
<td>NC-OC-FCS-001</td>
<td>Closed</td>
<td>No conformidades</td>
<td>Puesta en obra OC</td>
</tr>
<tr>
<td>000066</td>
<td>NC-EZF-FCS-010</td>
<td>Closed</td>
<td>No conformidades</td>
<td>Puesta en obra INS</td>
</tr>
<tr>
<td>000065</td>
<td>NC-EZF-FCS-009</td>
<td>Closed</td>
<td>No conformidades</td>
<td>Puesta en obra OC</td>
</tr>
<tr>
<td>000063</td>
<td>NC-EZF-FCS-004</td>
<td>Closed</td>
<td>No conformidades</td>
<td>Puesta en obra ARQ</td>
</tr>
<tr>
<td>000067</td>
<td>NC-EZF-FCS-011</td>
<td>Closed</td>
<td>No conformidades</td>
<td>Puesta en obra ARQ</td>
</tr>
<tr>
<td>000008</td>
<td>NC-OC-FCS-003 Andana Costat Mar</td>
<td>Closed</td>
<td>No conformidades</td>
<td>Puesta en obra ARQ</td>
</tr>
<tr>
<td>000007</td>
<td>NC-OC-FCS-003 Andana Costat Muntanya</td>
<td>Closed</td>
<td>No conformidades</td>
<td>Puesta en obra ARQ</td>
</tr>
<tr>
<td>000009</td>
<td>NC-OC-FCS-004</td>
<td>Closed</td>
<td>No conformidades</td>
<td>Puesta en obra OC</td>
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<tr>
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<td>No conformidades</td>
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</tr>
<tr>
<td>000050</td>
<td>NC-OC-FCS-005</td>
<td>Closed</td>
<td>No conformidades</td>
<td>Puesta en obra OC</td>
</tr>
<tr>
<td>000027</td>
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<td>Draft</td>
<td>No conformidades</td>
<td></td>
</tr>
<tr>
<td>000026</td>
<td>NC-OC-FCS-003 3D</td>
<td>Draft</td>
<td>No conformidades</td>
<td></td>
</tr>
<tr>
<td>000025</td>
<td>NC-OC-FCS-004 3D</td>
<td>Draft</td>
<td>No conformidades</td>
<td></td>
</tr>
<tr>
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<td>Draft</td>
<td>No conformidades</td>
<td></td>
</tr>
<tr>
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<td>Draft</td>
<td>No conformidades</td>
<td></td>
</tr>
<tr>
<td>000084</td>
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<td>Draft</td>
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<tr>
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<td>Draft</td>
<td>No conformidades</td>
<td></td>
</tr>
<tr>
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<td>Draft</td>
<td>No conformidades</td>
<td></td>
</tr>
<tr>
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<td>Open</td>
<td>No conformidades</td>
<td>Puesta en obra ARQ</td>
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<tr>
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<td>Open</td>
<td>No conformidades</td>
<td>Producción ARQ</td>
</tr>
<tr>
<td>000089</td>
<td>NC-ARQ-FCS-002</td>
<td>Open</td>
<td>No conformidades</td>
<td>Documentación QUALITAT</td>
</tr>
</tbody>
</table>

Reports for the non-conformities follows the same lines as the previously mentioned Issue Types as the concurrent main idea is to gain perspective of where the Issues are being created and to keep track of them. The template used for non-conformities included the typical Issue List template. The Issue List template permits the 2D drawing to be displayed at the beginning of the document and then list out all the individual pins by number. The author had to conduct some configurations to achieve this operation but the essence of the matter is that it can be done and the results are outstanding. Figure 4-63 is an example of this kind of report created for the non-conformities on Foc Cisell Station. The first image contains the pins and numbers then according to the order in which they were created, the second image is the list that conveys all the data behind the numbered 2D pins. The author decided that for non-conformities it could be worthwhile to experiment with other types of reports as non-conformities could mold better within the original design of what an Issue is in BIM 360 Field. The author chose to the Cumulative Issue Trend Report as this one endorsed the identifying the relationship between

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opened and closed non-conformities throughout a set timeframe. Figure 4-64 is an example of the Cumulative Issue Trend report generated by the author for the project. It is remarkable to note how the application of the tool reflects the truths explained by the author in the previous paragraphs, the opening and closing of non-conformities parallels the dates of the QA/QC meetings.

Figure 4-63: Issue List Report created for Non-conformities (Author)
Barcodes were also introduced for non-conformities as these can virtually situate the user inside the 3D model. Barcodes were already mentioned for their application in the documentation discipline within the BIM 360 Field Library but now the author wants to explain their implication in other areas of the software. Barcodes can be linked directly to individual equipment or assets carried from BIM 360 Glue to Field. Even if the user is working without a 3D model, the Excel template that requires filling in for the usage of BIM 360 Field has an optional barcode column embedded into it. Barcodes can be linked directly to these equipment and whenever scanned by the tablet application, the user is redirected to its location in the 3D model. This tool is offered by Autodesk, so the reader should not be amused by any of this information but what the author achieved with it. The author understood that the client was heavily invested in these non-conformities and anything that facilitated its review and interaction would be professed as rewarding. The author then decided that if barcodes could be adhered to individual assets throughout the 3D model, then he could select an asset within the vicinity of the non-conformity and select a favorable view that could serve as a barcode for the non-conformity. Figure 4-65 depicts two barcodes created for NC-OC-FCS-004 that were actually set for the stairway’s railway and a fire detector. Figure 4-66 shows the views that the user is virtually transported to whenever the two barcodes are scanned.

Figure 4-64: Cumulative Issue Trend created for Non-conformities (Author)
Figure 4-65: Barcodes used for Non-conformities (Author)

Figure 4-66: Non-Conformity NC-OC-FCS-004 as seen on iPad using barcodes assigned to the highlighted assets of the railway and the fire detector (Author)
5. Synchro Methodology

Synchro Software was the other tool utilized by the author to prove whether or not a BIM product could be tailored to meet the necessities of a Construction Management firm. After the author had several discussions with people around the industry, he realized that a tool that revolved around the idea of linking the planning and the on-site tasks and activities could prove to be a game-changer. The author discovered Synchro Software with its underlying products Synchro Pro and Synchro Site and tried to implement them for the L9 Foc Cisell Station. The application of this software was conducted in a different manner than BIM 360 as the author began experimented with BIM 360 before Synchro and decided that a second implantation could be useful to further prove that the tools available can enhance Construction Management firms.

Synchro Software is a 4D BIM and Virtual Design and Construction software platform that is both intuitive and simple for users to learn. Its solutions enable teams to improve the quality, the safety, the productivity and efficiency of their projects. The author focused his attention on Synchro Pro and its tablet application Synchro Site. “The intrinsic relationship between people, process and technology creates the foundation for successful construction project delivery.”[36] Synchro software excels at creating a highly interoperable digital technology platform whose main objective is to act as a catalyst for the construction industry evolution stemming from the traditional 2D planning and siloed workflows to a decidedly cooperative and efficient 4D visual planning and Virtual Design and Construction project management process.

Synchro Software’s solutions focus on allowing firms to create their own approach so that the product’s features can suit the demands of the project. From visualization gadgets, to big data analysis and monitoring of time-space conflicts, Synchro integrates interdisciplinary teams who engage and exchange information resulting in elimination of waste and increased value.[37]

5.1 Synchro Pro

Synchro Pro is designed to leverage the BIM to improve quality, safety, productivity, as well as to reduce costs on every project. The means to achieve this is through the use of real time visualization that provides a larger scope and better insight over the projects regardless of their stage in development. A major plus of Synchro Pro as a construction management tool is that it integrates a CPM scheduling engine that allows updating it then accurately reviews and presents the modified project schedule. Some of the properties that make Synchro Pro competitive are the following:

- Includes data on logistics
- Temporary works and allocation of resources
- Conflict resolution in design, space and time
- Highlights unsafe work conditions
- Validation of approach throughout the construction phase

All of these are implemented on a cloud system that permits for plentiful users to be connected which furthermore improves data availability. Synchro PRO is a 4D project scheduling system that has gained fame for its characteristic feature of allowing users to import their own design files into the system in order to have a visual, time-lapsed representation of what the project
should look like at any given point in its life cycle. The software is also endowed with clash detection and reporting capabilities which alerts the users whenever there is a potential construction complication.

Some of Synchro Pro’s capabilities include the following:

- **Ability to auto-match BIM model to schedule to update the construction plan in 4D**
  - The author experimented with varying methods of transporting the 3D model into Synchro Pro and determined that the add-in offered for many of the ordinary modelling software was better than simply importing an IFC formatted model. Synchro Pro allows the users to import models from up to 10 different modelling software but their main representatives in Madrid explained that the best way to keep the information as virgin and complete as possible was to install the add-ins and export the model directly from these software. The author used both Autodesk Revit and Navisworks to create a merged model that could later be transferred into Synchro Pro.
  - The project schedule was created using Microsoft Project and this software was compatible with Synchro Pro so its transition was smooth. Once both the 3D model and the schedule were within Synchro Pro, the author could associate both elements with specific tasks within the schedule.

- **Reduces schedule variance with visual look ahead reports that identify activities, work areas, and equipment**
- **Reduce cost variance using comprehensive resource management, planned vs. installed quantity tracking, earned value, critical path, and many other**
- **Tool that enables leading project review as the Synchro model can be used as the central hub of information for clear, collaborative and productive planning as well as interdisciplinary decision-making**
- **Foreseeing activities and planning for its safety hazards and risks before commencing work at the jobsite using dynamic spatial coordination analysis that identifies work area overlap, overhead crane risks, potential for obstruction delays, and others**

The author had to complete several courses on Synchro Pro as the tool demanded extreme user preparation for a correct implementation. The author assisted several conferences on the software in Barcelona and Bilbao and various webinars on more specific subjects. The certificate for Synchro Pro is detailed in Annex 6 as well as one for the previously described software of BIM 360.

### 5.2 Synchro Site

Synchro Site is the tablet application that closed the gap between office work and on-site activities. Synchro Site connects with Synchro Pro via cloud service and allows real-time updating of the different tasks and status of the resources so that the data is accessible and available to everyone involved with the project.\[38\]

Synchro Site’s participation in the Foc Cisell L9 project was to gain further perspective of what was happening on the field and how the production effected the original schedule. The configuration had to be performed on Synchro Pro to create many types of filters that will be explained later and alleviate the data usage of the iPad. These filters also enabled viewing features that complimented the implication of the product. Some of the key features offered by this product are the following:
- Reviewing of tasks to keep a tight monitoring methodology of the project evolution
  - The author went once a week on-site to conduct verification of the status of these tasks in relation to their theoretical advancement from the project schedule.
- Breaking-down the work required and the resources linked to a task. These status resources can be customized in many different ways to facilitate their updating on-site.
  - The author took advantage of the weekly on-site visits to validate the status of the assets linked to the tasks. This means that if the task of ventilation was supposed to be complete, but the author noticed that the fans were not connected, he would appoint a status that compiled this information and once the data was all synchronized, the schedule would be updated to reflect these lags and differences.
- Attaching Notes and Photos to individual 3D elements that can be viewed from Synchro Pro on the computer
  - The author used these exclusively to serve as evidence of why a status was assigned the way it had. These statuses could also be implicated with issues and the author benefitted from this permissibility to attach non-conformities to individual 3D elements.

5.3 Implementation

The linking of the Foc Cisell project schedule to a 3D model is achieved by implementing the BIM methodology and coupling it with the Synchro Pro. The author wanted to create a system that is pioneer in its kind as the implementation of Synchro Software both in the design phase and in the construction phase for construction management and technical assistance services has yet to be developed. The author believed that with these tools he could adopt the software to a construction management firm and pave the way for the methodology.

The Synchro Pro has its mobile modality through the Synchro Site application, giving an added value in terms of monitoring and planning on-site. The streamline of the tablets ensures that the information will be interconnected, the control of the status of the activities in terms of QA/QC, supervising the actual quantities installed and control of the on-site production, with the objective of obtaining information from the asset’s status in real time during the construction phase as well as guaranteeing the historical information of work.

One of the main benefits of using the system is that the people involved in the project will be aware of the status of the works in real time. The author had to complete several webinars and courses to understand the tools and work-methods of Synchro Pro and Synchro Site.

Construction Management firms are striving to offer BIM4D services as its potential in terms of traceability of the information collected in the field, improvement in QA/QC from the smallest of scales in individual activities all the way to larger components and their construction; all which leads to earned value and an augmenting of the ability to compete with other firms.

The methodology presented in the next following sections was detailed by the author recommended by AECOn and Synchro Software professionals. The benefits of applying Synchro in tasks proper of a Construction Management firm includes the typical BIM benefits of working with a 3D model and attaching information and all of the linkage involved but also
the enabling of a whole other dimension, the 4D. The fourth dimension refers to time and Synchro Pro is considered by many around the world as one of the leading products in terms of a planning tool that also encompasses a 3D model and the ability to close the gap between these two deeds. Some of the software that are leading the industry in the planning expertise include Primavera P6 and Microsoft Project but these fail to grasp the essence of BIM as they do not possess any 3D model characteristics.

The author used Synchro Pro to automate site reports, have a real-time visibility of inspection activities, ensure control over purchase priorities and waste reduction, fine tuning of the overall planning to accommodate the reality as seen on-site. Figure 5-1 displays a screenshot obtained from Synchro Pro’s movie application that allows the users to see the way the 3D elements are being erected based on the current Gantt Chart. Object shadowed in green correspond to the elements that are currently being installed for whichever time frame is chosen.

Synchro works through a collaborative platform in the cloud that allows multiple users to work on a project simultaneously in both desktop and mobile applications. The project format “Workgroup Project” is hosted in the Microsoft Azure cloud allowing any user's changes to be displayed in real-time. The Workgroup Project is the name of the official project uploaded into the cloud and whose Synchro Site application can bond with. Figure 5-2 illustrates the workflows behind the software. This diagram is the general scheme of application for Synchro Software and was the one utilized for Foc Cisell station. The author received training on all of these to ensure that he was capable of handling the tasks and heavy load of information stipulated.
Synchro Pro is a 4D integrated platform for that roots from the necessity of having a scheduling product powerful enough to convey data to the next level. From the native BIM file of the project, the author had to link the schedule of the project with the model according to the construction phases, the mandatory milestones and the associated purchasing processes, among others. An important aspect that has to be noted is that the software itself encourages users to schedule inside of Synchro as it is also capable of man-handling these duties but also warrants the uploading of a project schedule from most scheduling software. The author worked around both of these features as the station’s schedule was designed on Microsoft Project but also required some amendments so that it met the purposes of the implementation. The linking of the 3D elements with the Gantt has to be done manually but Synchro Pro facilitates the process by endowing match-making configurations that can be set into place by simple programming. Synchro Pro uses the CPM method to recalculate the schedule every time an activity’s time is changed either by means of a delay or an earlier start. Figure 5-3 is an image of the author performing an inspection by means of the Synchro Site application for the iPad.
The configuration of Synchro Pro is an essential puzzle-piece in the success of the author’s implementation as it required an understanding of the software whose features were broader and required good construction management knowledge. These conclusions are withdrawn after implementing other software tools such as BIM 360, Power BI and TCQ.

It was necessary to carry setting-up configurations since the very get-go as the linking of the schedule and 3D model had to be precise and would be the bedrock for the entire pilot project. The author knew the project’s schedule and its planning but was not an expert on the discipline of architecture or MEP so meetings had to be brought up to ensure that the 3D elements were interlocked with the appropriate lines of the Gantt Chart. Furthermore, much of this process is based on the previous work performed on the modelling software as the names and properties of all of the elements were transposed into Synchro. The author had to dig deep within the Revit model to comprehend where the model lacked information and to create a platform of improvement for these models.

The objective of the author in this application was particular and sought to prove that even project scheduling and project monitoring can be achieved by products out there in the market that may be acquired by construction management firms. Figure 5-4 depicts the work processes before and after the application of BIM methodology. The typical scenario embroils chores that are marginalized and dealt with in a one-to-one manner whilst the author’s vision is to adapt all these tools in the best of way to eliminate waste and build bridges on gaps that seemed to be insurmountable.
The author’s expertise founds on the fact that he is the responsible for the QA/QC discipline in the L9 Foc Cisell Station Project so his interests rely on proving how these products yield earned value and improve the discipline as a whole.

The Synchro Pro system can be paired with other software to optimize the QA/QC of the project during its construction phase but still shows that it can be adopted to serve the ambit at a high level.

The author’s application of Synchro Pro on Foci Cisell orbited around the association of elements to the Gantt Chart and then attempting to see what the software could do in terms of established processes versus new ways of working the task. The status of the assets or resources proved to be one of the most important aspect of the software because watching how the project was being constructed via assigned colors on statuses emanated information and conclusions that would have been impossible to make without it. The resource statuses had to be configured on Synchro Pro and allowed for maximum personalization, so the author determined to use color scales for maximum viewability purposes. As an example, some of the statuses compiled and set for elements of different discipline were:

- Non-conformities
- Damage
- State of Purchase
- Received
- Collected
- Item placed
- Revised
- Approved
- Finished

As a status is assigned to an element, the color of the element in the model is altered thus consenting a swift virtual visualization of the state of the work. Figure 5-5 displays the statuses the author set on Synchro Pro which are the ones normally utilized on the Foc Cisell project.

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The updates pertaining the resource statuses are stored in a history which guarantees the traceability of the activities over time as well while observing which elements inflicted or prevented the fulfillment of predetermined milestones. Another functionality that is worth noting is the ability to generate animations of the erection of the structure in a user-friendly and intelligible way rooted from the verifications of the status of the resources of the elements in the field. Since the author was making weekly visits with the iPad, he was responsible of assigning the statuses to individual elements or even collectively. The data was stored within the elements and after a month or so, sufficient status changed had been performed so that a movie script could illustrate the alterations these elements had undergone. This function was extremely attractive as it went further than the mundane feature that allows 3D elements to assemble together as they are placed within the project schedule. The function was displaying the actual life-cycle of the equipment and elements on-site, from its reception all the way through their installation. Figure 5-6 displays the tablet’s screen when performing a resource status inspection. This case shows the ventilation fans and their associated status of installed. It might be valuable knowing that statuses can be appointed to elements as a group or individually, the perk of doing it on a one-by-one manner is that it then unlocks the feature of adhering photos and notes to the specific asset. Figure 5-7 represents the movie making feature imbedded on Synchro Pro that lets the user gain insight of the status of the assets on a given point of the timeline. If matching both of the figures presented below, the reader may understand which MEP elements are assigned to which statuses.
Figure 5-6: Resource Statuses as seen on the Synchro Site Interface (Author)

Figure 5-7: Movie Making feature as seen on Synchro Pro (Author)
To streamline the process of transferring the Synchro Pro model to the Site, filters have to be created to visualize specific elements in such a way that the inspector in the field will visualize those activities associated to the filter. The first type of filter is a 3D filter which is basically a summarizing and grouping of elements by typology or a common denominator they may share. The author decided to create these by discipline and therefore subdivided the elements by architectural and MEP. The reader may remember that these were the elements modelled with the highest LOD and described in earlier sections of the dissertation paper. These 3D filter can be customized up to a point where the user can decide what to do with the unfiltered elements. Figure 5-8 illustrates one of the trial 3D filters the author created when segregating MEP elements, he opted to shade the unfiltered elements so that the users could still garner the location of the filtered elements with respect to the station.

Other filters that affect ease of use are the appearance profiles and their importance stems from their capacity to customize the way in which the 3D elements linked to the planning are visualized when moving through the time in a virtual manner. The appearance profiles are an important part of Synchro Pro because the way in which these 3D elements combine to constitute the whole starts and finishes within these profiles. Synchro Pro presents some appearance profiles that match the nature of an element in a construction site, install, temporary, maintain and remove. Before attempting to link the 3D elements to the activities in

Figure 5-8: 3D filter for MEP elements as seen on Synchro Pro (Author)
the Gantt Chart, the nature of the object must be set so the software understands what the user desires to do with that object. The author created an appearance filter called Instalar and modified the colors to see the repercussions of its modification. The outcome from the invention of the appearance profile was null as the difference between the standard profiles proposed by Synchro and the authors was insignificant.

Whenever the author conducted an inspection and decided to modify the status of one of the elements, he attached documentation so that the information would be safeguarded within the object. As mentioned previously, the elements are linked to documentation and information such as photographs of work associated with a state of the element or notes. In the case of generation of non-conformities, these will be supported with the corresponding photographs at the time of the inspection and will be stored in the history of the element indicating the date, the user who has detected the non-conformity and simple notes.

![Photographs attached to elements as seen on the Synchro Site Interface](Author)

The product also enables inspections regarding the tracking of delays in activities through activity statuses. The on-site inspector selects the elements whose activity status does not adhere to the original project schedule (either earlier start or delayed) and changes its status on the tablet. These modifications in status on Synchro Site are synchronized into the cloud, the original schedule is automatically modified to compensate for these alterations in time and recalculated the critical path. Figure 5-10 symbolized the work that must be performed to
change the status of the task. The author also includes a % Complete as this will be taken into account whenever Synchro Pro recalculates the CPM. Back in the office, the planner can visualize in the Gantt the activity that underwent the change as shown in Figure 5-11. The bar of the activity will have different colors that represent the delays or advances detected in the work which provides some wiggling room to act on the modification and readjust the activities to account for this. The author also had to

![Figure 5-10: Task Status modification as seen in Synchro Site (Author)]
Annex 7 was created as a summary of the implementations the author applied on the Foc Cisell Station of the L9 Project for both software. This Annex serves a simplified representation that may serve as a guideline for the readers so that they can perceive the main applications and deepen their knowledge on the implementation if desired.
6. KPIs

A key performance indicator (KPI) is a type of performance measurement that evaluates the success of an organization or a particular activity in which it engages. Progress can be interpreted in varying ways, it might be a periodic achievement of an operational goal or simply by making the leap towards a strategic goal. KPIs are industry and even project focused, the performance of an activity may prove to be of greater importance to one company to another. The need to grasp the success and progress within a project, assessing the present state of the business is essential to set benchmarks that can be used as the standard to compare to.

The BIM implementation for the Foc Cisell Station of the L9 Project required establishing KPIs to determine the feasibility of the application of the tools and methodologies developed by the author. Even though the dissertation paper was more focused on whether or not the application was possible and fruitful, key performance indicators would then either back the author’s findings or dispute his theories.

The first step to configure which KPIs would be utilized in the project was to define a set of values against which to measure. The author was obliged to conduct a two-step process to learn the pros of the post-application. The author had to calculate the amount of time current processes demanded while completing a specific task. The reader should note that most of the statistics that will be mentioned in this section are derived from time calculations, the author invested his time on measuring how the application would save time and then the time could be converted to other useful parameters such as cost or even occupational health and safety.

The two categories of measurements that comprise KPIs are the following:

- Quantitative which symbolizes data that cannot be distorted through personal feelings, prejudices or interpretations. These facts are objective in nature and are typically conveyed as a numeric value measured versus an established standard.
- Qualitative represents values that are influenced by human nature, these are generally presented as a textual value which have endured interpretation of some kind.

The difficulties of the measurements stemmed from the datum that KPIs may only be measured versus the past. This meant that for every creative idea the author had on how to measure the benefits of the implementation, the data for the current activity being scrutinized had to be available and reliable.

Some of the basic KPIs mundanely used in construction are the following:

- Number of accidents
- Number of accidents per supplier
- Actual working days versus available working days
- Cash balance - Actual versus baseline
- Change orders - Clients
- Change orders - Project manager
- Client satisfaction - Client-specified criteria
- Client satisfaction product - Standard criteria
- Client satisfaction service - Standard criteria
- Cost for construction
- Cost predictability - Construction
- Cost predictability - Construction (client change orders)
• Cost predictability; Construction (project leader change orders)
• Cost predictability - Design
• Cost predictability - Design and construction cost to rectify defects
• Customer satisfaction level
• Day to day project completion ratio - Actual versus baseline
• Fatalities
• Interest cover (company)
• Labor cost - Actual versus baseline
• Labor cost over project timeline
• Liability ratio (over asset) on current versus completion comparison
• Number of defects
• Outstanding money (project)
• Percentage of equipment downtime
• Percentage of labor downtime
• Percentage of backlogs over project timeline
• Percentage of unapproved change orders
• Productivity (company)
• Profit margin - Actual versus baseline profit margin over project timeline
• Profit predictability (project)
• Profitability (company)
• Quality issues at available for use
• Quality issues at end of defect rectification period
• Ratio of value added (company)
• Repeat business (company)
• Reportable accidents (including fatalities)
• Reportable accidents (non-fatal)
• Return on capital employed (company)
• Return on investment (client)
• Return on value added (company)
• Time for construction
• Time predictability - Construction
• Time predictability - Construction (client change orders)
• Time predictability - Construction (project leader change orders)
• Time predictability - Design
• Time predictability - Design and construction
• Time taken to reach final account (project)
• Time to rectify defects[39]
6.1 KPIs BIM Methodology

The outcomes of the BIM application on the Construction Management ambit enriched all the activities of the management process as the implementation poured throughout the streamlines of the project. These newly created channels of information increases the productivity of the process as a whole and reduced work inconsistencies or involuntary omissions.[40]

The design and planning stage has proved to be the phase most in-sync with BIM methodologies and 3D models, but the application of these during the construction stage benefits the project as the emphasis is then shaken towards task sequence analysis while maintaining the job planning side of the project on a good-standing. This planning phase may not be ignored as it is critical and conditions the success or failure of a project from the get-go. Sensible planning enables the opportunity of taking corrective actions in the affair of unforeseen events. BIM technology applied to project management brings numerous productive advantages and QA/QC to the jobsite, paired with greater visual communication of the project with all participants, even those without narrow technical training as was the case with some of the subcontractors in Foc Cisell that are focused on an area of expertise but may not comprehend the overall scope of the project.

Throughout the dissertation paper the author has stressed and highlighted benefits entailed in a correct BIM application in areas such as monitoring and control of the jobsite. In general, the use of the BIM allows extracting and elaborating a documentation of greater precision and added value. Even if the work interfaces are fed through different mechanisms, the uniqueness of BIM lies on the converging of the information which then exacerbates the possible inconsistencies that may exist in the different activities. At the same time, optimizing time-space environments is possible because of the feature of BIM models to serve as a collaborative environment.

The author’s objectives of the application of the BIM as a Construction Management tool included the very important aspect of reduction of costs while assigning a more detailed control of them. Some of the reasons acknowledged by the author throughout the paper attribute to reduction of costs, but a vital cornerstone of the implementation was the detection of possible conflicts due to the virtual simulation of the construction process of the project. This simulation of the construction works and the configured connection to the project’s schedule encourages determining both constructive incompatibilities as well as the opportunity to perform tasks at the same time. A good study and development of the project in the design phase allows anticipating the possible problems that may occur later in the construction phase of the work which is why the wholeness of the pilot project requires that the BIM implementation is initiated from the moment that a bid is won. The author’s situation was one where he had to start during the construction stage and optimize the methods used with a righteous BIM application.

The author’s convictions lie in the fact that the vast majority of professionals who currently apply BIM methodology in their projects doubt that both the BIM systems and the traditional system based on the CAD can coexist. The advance and development of both tools and software will make CAD systems give way to BIM modelling programs. Fighting in two fronts is not the answer, the industry is immersed in a digitized revolution and BIM technologies seem to the safe bet.
6.1.1 Quantitative KPIs

This subsection will consist of the KPIs the author experimented throughout the BIM application on Construction Management functions. These KPIs were thought-of while the author was conducting the implementation as his main goal was to prove the possibility of employing market available software as a tool to execute tasks proper of a Construction Management firm.

Table 6-1 summarizes the productivity improvements at task level resulting from the deployment of BIM 360 Field/Glue. The values serving as inputs in the table are based on real data recorded during the author’s implementation on Foc Cisell. This table summarizes the major KPIs in an accessible manner so that the readers can analyze the before and the after. A more in depth and prolonged study with a wider user group could reveal further efficiency productivity savings. It should be noted that the 9.5% productivity improvement as documented for the author’s implementation is broadly in line with the 5 – 8 % industry norm for the deployment of digital field technologies in construction. This table only portrays the numbers obtained from author’s implementation but to understand the background behind these, the reader must head to the Issues subsection to see how the optimizing permeated through the workflows of the project. These values were obtained after measuring the time it took to complete the tasks by using the traditional existing method and then contrasting it with the new methodology created by the author. These measurements are raw estimations that derive from real measurements performed and depict the benefits of a righteous implementation.

Table 6-1: Quantitative KPIs from Foc Cisell Station (Author)

<table>
<thead>
<tr>
<th>Existing method</th>
<th>Duration (minutes/week)</th>
<th>Risks/ Time in paper</th>
<th>BIM 360 Field based method</th>
<th>Duration (minutes/week)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Recording Issues (Non-conformities)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average of 3 per week, 20 minutes per Issue Paper. 2 minutes per issue digital with BIM360</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Recording Issues (Testing of Materials)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average of 3 per week, 20 minutes storing on server and on Excel, 2 minutes per test with BIM360 on-site and 5 minutes per test with BIM360 on office</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Recording Issues (Sound Pressure Level Measurement)</td>
<td>141.25</td>
<td>Time to transcribe from paper to digital, attach the photo, log and email via project spreadsheet. Storing in server for traceability purposes.</td>
<td>Immediate digital recording with photos and documentation and notifications to entity responsible.</td>
<td>34.6</td>
</tr>
<tr>
<td>1. Recording Issues (Plastic Tell-Tales)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average of 2.8 per week, 5 minutes per object, 2 minutes per measurement with BIM360</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Qualitative KPIs

This subsection will consist of the KPIs the author experimented throughout the BIM application on Construction Management functions. These KPIs were thought-of while the author was conducting the implementation as his main goal was to prove the possibility of employing market available software as a tool to execute tasks proper of a Construction Management firm.
A brief feasibility study was conducted using the numbers the author estimated were required for a complete implementation of BIM 360 on Foc Cisell. The application of the product on the station was conducted by the author himself and simulating interactions with other subcontractors to learn the strengths and weaknesses of the software. The author decided to extrapolate data and the valuable lessons obtained to analyze the earned value that could entail the participation of multiple users. Table 6-2 summarized the study illustrates the productivity/efficiency gain attributed to utilizing BIM 360 Field on the Foc Cisell L9 Project. The calculation assumes 5 users each working a 45-hour week and with an average cost per hour of 40 Euros per hour. This cost includes salaries, pension, health care, on-site insurance. The 9.44% efficiency gain was obtained in Table 6-1.

Table 6-2: BIM 360 Productivity Gain for Cisell Station (Author)

<table>
<thead>
<tr>
<th>Construction Field Management Productivity Gains</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Users of BIM 360 Field</td>
<td>5</td>
</tr>
<tr>
<td>Average hours worked per week</td>
<td>45</td>
</tr>
<tr>
<td>Average fully burdened hourly rate</td>
<td>40</td>
</tr>
<tr>
<td>Number of Construction Months</td>
<td>18</td>
</tr>
<tr>
<td>Efficiency gain via BIM 360</td>
<td>9.44%</td>
</tr>
<tr>
<td>Construction project hours saved</td>
<td>1147</td>
</tr>
<tr>
<td>Associated project savings</td>
<td>€45,878</td>
</tr>
</tbody>
</table>

Once the values on Table 6-2 were computed, the ROI for a BIM 360 implementation on Foc Cisell could be performed. The Return of Investment calculation was generated using the formulas listed below in Figure 6-1 and the values were obtained from the calculations previously presented. These formulas were used to complete Table 6-3 that symbolizes the astounding benefits gained from a correct BIM 360 Implementation on the author’s project.

\[
ROI \% = \frac{\text{Gain from Investment} - \text{Cost of Investment}}{\text{Cost of Investment}}
\]

\[
ROI \% = \frac{€45,378 - €7,232}{€7,232} = 534 \%
\]

Figure 6-1: Return on Investment formulas for Foc Cisell Station (Author)
Table 6-3: Return on Investment for Foc Cisell Station (Author)

<table>
<thead>
<tr>
<th>Cost of Investment for 5 Users</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardware cost (5 iPads at € 550 ea.)</td>
<td>€ 2,750</td>
</tr>
<tr>
<td>Software cost</td>
<td>€ 4,482</td>
</tr>
<tr>
<td>Cost of Investment</td>
<td><strong>€ 7,232</strong></td>
</tr>
<tr>
<td>ROI</td>
<td>534%</td>
</tr>
</tbody>
</table>

These values merely scratch the surface of a well-executed feasibility study and Return on Investment analysis, but the author’s objective was to convey the idea that Autodesk BIM 360 Field can reduce the time spent in the administration of on-site construction processes, time that could be better spent on value adding tasks. A 9.44% efficiency/productivity gain can then be applied to more value-adding tasks to avoid rework and provide an even greater return. Improved productivity assists rework avoidance by increasing face to face supervision time instead of “doing admin” in the site office.
Conclusions

7. Conclusions

The author’s goal for the dissertation paper was to instill the idea that the BIM software available in the market can be suited to meet tasks and activities specific to the Construction Management ambit. The primary goal was to prove that it is indeed possible to implement these products through methodologies the author created to ascertain his purpose. The latter part of the document discusses the tangible benefits generated by a righteous application of these BIM methodologies.

The chapter BIM 360 Methodologies discusses the capabilities of the Autodesk software utilized to experiment on the author’s aim. The BIM 360 platform conforms a list of products that were designed to focus on a specific stage of the construction project’s lifecycle. The main products used by the author to deploy the Foc Cisell’s pilot project were BIM 360 Glue and BIM 360 Field. BIM 360 Glue’s role in the BIM application could be fundamentally understood as the bridge that gaps the individual 3D models and BIM 360 Field. BIM 360 Glue’s capabilities are discussed as it is a powerful tool that handles pre-construction interactions. Some of these functions include the ability to merge individual 3D models compatible with many formats and modelling software and a competent clash detection and review tool. BIM 360 Field is the primary product used for the BIM application in Construction Management. The discussion around this product in this section of the document emphasizes the program’s potentials and the author side-notes the way that he applied these on the Foc Cisell Station. This section dealt with the implementation of the product onto a project by limiting to what the product’s goal is and its guidelines. The author demonstrates the vast amount of advantages that are generated whenever the software is employed on a project like the elimination of waste byproduct of rework, improvement of quality and promotion of safety. These may be achieved by setting-up checklists, automation of reports, creating bar codes for assets, document traceability, and others. This chapter’s purpose was to educate the readers so that they could comprehend what the product allows users to do and create their own visions of what they would want to do with it.

The chapter Straying from the Path and Creating a Methodology is the bread and butter of the dissertation paper. This chapter is grounded on the previous chapter but now enlarges the scope of the implementation by attesting how the software can suit much more than what it was originally designed for. Even though this statement may seem arrogant, the author is simply trying to show that once the software is completely understood, it can be configured to enhance other activities and tasks. The author is stretching the boundaries of the product to meet the expectations of what a BIM implementation on a specific activity would entail. He executes this by creating methodologies for each of the applications and reasoning his thought process as well as the why it should be done this way.

The author starts by listing the main tabs within BIM 360 Field and how he used them, which differed from its intention. The first one was the Library tab and the author explicates the logic behind linking certain documents with locations and the folder structure required for maximum yield. The methodologies for configuring tags and barcodes is also stated whose importance is uprooted in the ease of navigation through the Library. The Checklists tab is another one that the author mentioned that an entire dissertation paper could be written of them because of the many links and utilities these emanate. When the author was deciding whether to focus on these or on Issues, he had to confront the famous conundrum of who came first, the chicken or the egg. This due to the fact that Issues are supposed to be created via Checklists but both of them
could be modified to successfully achieve a goal. Checklists can be personalized in such a way that they reflect the diverse purposes of the user and even for situating specific Issues within a 2D location. The author executed the latter choice as he vehemently believed that Issues lie in the core of the software, even if they were meant to be triggered by Checklists, they command enough power to be created and stand in their own.

The Issues module of the paper relate to the author’s contribution to the industry and how he invented a methodology to use these in any shape and form possible. His main implementations of these Issues included Sound Pressure Level Measurements, Material Testing and Analysis, Plaster Tell-Tales and Non-conformities. These were all created as Issue Types and focused on tasks the author was required to complete on a daily basis on the Foc Cisell L9 Station from a QA/QC standpoint. The author illustrates the methods behind the implementation as well as the results in form of tangible benefits that the reader can visualize through the screenshots presented. The author records his works as well as the way he confronted every obstacle and portrayed the option he thought was most viable. Some of these obstacles were identified beforehand and were resolved through the use of Custom Properties and Issue Templates.

The author stresses that the implementation deemed vital was the one on Non-conformities as these comprised a formidable level of importance from the client. Non-conformities inscribed in the software covered the four main disciplines involved in the project: architecture, MEP, heavy engineering and QA/QC. The processes before the BIM implementation were crystal clear to the author as he is solely responsible of monitoring and opening/closing them so the pros and cons of the digitization through BIM 360 Field were well-founded. The author’s discoveries closely followed his previous conclusions that the application could simplify and improve the quality of work while providing a more visual manner to display information. The automation of reports confirmed that the implementation enhanced the workflows of the author as the same data that was originally stored would then generate configurable reports that could be scheduled and sent to other people and firms.

After the BIM 360 Field implementation, the author toyed with the idea that maybe he could find another product that dealt more with the planning side of the project. After intensive research, the author opted for Synchro Software as its credentials seemed impeccable and also contained a tablet application that could work parallel to BIM 360. Synchro Pro is the desktop interface and is a standalone 4D software that shines around the idea of linking a project schedule with 3D models. This innovative idea means that as the schedule progresses in time, the users can visualize how the distinct elements come together to form bigger lots and eventually systems. The author applied a plainer methodology when approaching Synchro as the capabilities of this software far exceeded the ones of BIM 360 and demanded more training and instructions. However, the author was still able to withdraw that this software was also capable of marking specific resource and task statuses that could be molded around the author’s needs.

The last chapter of the document refers to some key performance indicators that were set before the implementation and the outcomes of these as the methodologies were applied. The author separated the key performance indicators in two categories: quantitative and qualitative. For quantitative the author presented a table with before and after values and descriptions and the direct impact of the implementation in specific tasks and activities. The results all seem to match or exceed the author’s convictions and statements as time required to complete these categories was diminished while increased efficiency. Qualitative-wise, the author displays a
simply table that explains the costs incurred for the implementation to take place versus the earned value from the previous section to determine a return of investment of 534%.

The author establishes that a BIM implementation using the methodologies developed in this dissertation paper on activities proper of a Construction Management firm is both advisable as well as feasible. The benefits of the implementation are not limited to what the software allows the users to do with it but to the extents of the user’s imagination on how to better utilize it to achieve the set goals. The author proves that the advantages of a well-constructed implantation include increasing profit margins, greater efficiency and productivity, increase of market share as the I+D section of the bid grows, better traceability of the documentation, improvement in QA/QC, promotion of safety and a boost in the management of the assets.
8. References


[15] Henderson, 7Ws elimination of waste – Management training article, PHS


Fernán Vargas Renzi
References


9. Annexes
ENTREVISTA IGNACIO VALERO

1. APLICACIÓN BIM EN CONSTRUCTION MANAGEMENT
   A. ¿Por qué cree que el BIM se ha enfocado tanto en la parte de diseño y menos en construcción y el mantenimiento y operaciones?
   B. ¿A qué se debe que la industria de la construcción tarde tanto en adoptar las metodologías de BIM cuando ya ha triunfado en otros sectores?
   C. ¿Por qué apostaría una industria en invertir tecnología y metodologías BIM? ¿Qué beneficios tiene y cuáles son los obstáculos principales?
   D. ¿Nos podría comentar de algunas de las investigaciones llevadas a cabo por estudiantes o profesores de la UPC en materia BIM que a usted le llame la atención?
   E. ¿Por qué cree que España le cuesta tanto moverse con la tecnología y entrar en esta digitalización que es inevitable?
   F. ¿Usted cree que el BIM es una herramienta tan poderosa que eventualmente forzará a todas las compañías a implementarlas en sus proyectos?
   G. ¿Cree que el uso que se le está dando al BIM en España hoy en día es el óptimo? ¿No será que se está utilizando mucho como herramienta para vender pero menos en disfrutar de sus beneficios?
   H. ¿Ha escuchado de casos de una Dirección Facultativa o de Obra utilizar programas de BIM para gestionar un proyecto? ¿Cuáles?
   I. ¿Qué softwares ha experimentado con y cuál es su opinión general de ellos?
   J. ¿Cree que vale la pena para una Dirección de Obra implementar software con aplicaciones BIM para administrar mejor una obra? ¿Qué beneficios le ve a esto?
   K. ¿Adónde cree que vamos con el BIM y cuál es su visión a los 5, 10 y 20 años?
FERNAN: Buenas tardes, estamos hoy con el profesor Don Ignacio Valero de la Escuela de Caminos y Canales y Puertos de Barcelona. Vamos a hablar un poco sobre temas BIM y su aplicación en lo que es construction management. Entonces, muchísimas gracias por venir, Don Ignacio.

DON IGNACIO: Al contrario, gracias a vosotros por invitarme, es un placer siempre estar con nuestros estudiantes.

FERNAN: Entonces, vamos a hablar con unas preguntas que hemos confeccionado, y la primera sería:

1. Don Ignacio, por qué cree que el BIM se ha enfocado tanto en la parte de diseño, y menos en construcción, y en mantenimiento y operaciones?

DON IGNACIO: Si nos referimos a lo que ha sido la entrada del concepto BIM, filosofía BIM y después unas herramientas que van anexas al concepto. En nuestro país, en España, lo cierto es que ha irrumpido como un tsunami. Es decir, nosotros sabemos que en otros países, por ejemplo en prácticamente todos los de ámbito anglosajón, tradicionalmente y desde hace tal vez 15 o 20 años, están trabajando con repositorios digitales combinados, como es la filosofía BIM. Y a España esto llega prácticamente como una imposición de ponerse al día a nivel europeo. Siempre que pasa esto en un sector como es la construcción en España con raigambres muy antiguas, con mucha inercia al cambio, se genera una dificultad. De tal forma que el sector ha tenido que interpretar el por dónde empezar, pues yo diría que por el eslabón más sencillo, que es el proyecto. Por qué? Pues porque en el ámbito del proyecto al menos herramientas como Autocad ya son de uso común en la silla de profesionales. Aquí en CIMNE y seguramente después hablaremos de esto, trabajamos en investigación sobre la aplicación de eso al ámbito obra, y vemos que aliviaría muchas más dificultades para un gabinete organizado de arquitectura o de ingeniería, y entiendo es más fácil, y eso ha sido el origen de empezar por el diseño.

FERNAN: Profesor, don Ignacio, a qué se debe que la industria de la construcción tarde tanto en adaptar tecnología BIM cuando ya se han adaptado en otros sectores de la industria?

DON IGNACIO: Bueno, la construcción pertenece al sector servicios. Bien, pero yo creo que no es ajena a las mismas dificultades que probablemente tuvo cuando se implantó en otros países. Quizás hay países con tendencia a la introducción tecnológica con más facilidad, pero España no lo es. Nosotros tenemos sectores fuertes en ámbitos, como por ejemplo la agricultura, que probablemente en otros países también han introducido digitalización. Pero España no olvidemos, por ejemplo que la investigación está a la cola casi de Europa, y esto incluye países no de habla inglesa que tienen unas características pues bien diferentes, y por lo tanto, estamos viviendo la transición natural. Tardamos más o menos? Bueno, es un camino que al menos los grandes agentes, y por los grandes agentes entiendo el hecho de que esas constructoras españolas estén siendo exitosas trabajando en todo el mundo. Si por ejemplo, yo hablo con mis amigos de una empresa como ferrovial en Londres que han estudiado aquí conmigo ellos, bueno están trabajando con BIM de forma natural desde hace mucho tiempo, porque en Reino Unido se trabaja así. Por lo tanto, no es tanto problema de las organizaciones como de los trabajadores que tenemos aquí, la formación universitaria que damos. En una escuela como la nuestra, no tenemos todavía formación reglada de los estudios en materia de...
BIM. Esto debería ser una asignatura troncal, y no lo es. Los motivos a partir de ahí son claros. Los chicos están saliendo con poca formación aún, las empresas no lo conocen, el tiempo es el que marca la formación.

FERNAN: Por qué apostaría una compañía de Construction Management en tecnología y metodologías BIM? Qué beneficios tiene y cuáles son los obstáculos principales en su opinión?

DON IGNACIO: En parte, los obstáculos vienen a ser un poco los que ya estamos empezando a destacar, no?; el beneficio, es evidente. Por ejemplo, hay un concepto cuando yo he hablado con las empresas tanto de Project Management como las constructoras que ahí hay unas fronteras difusas, me comentan, que es la fase de repasos de obra, tanto en edificación como en obra civil. Aquí estamos manejando presupuestos en el orden del 2%, en finalización de obras. Es decir, tareas que quedan para el final y que no han acabado de resolverse bien, o que contienen errores que el usuario reclama al final de la fase de construcción. Y me refiero mucho a la fase de construcción cuando en realidad los beneficios que yo veo de más interés en la filosofía BIM son a largo plazo, porque, si se dispone de un repositorio digital en el cual tienes un proyecto as built bien construido, dentro de una herramienta, cuando tienes que hacer por ejemplo tareas de mantenimiento, esto es un ítem para mí básico. Por ejemplo, tenemos en España una red ferroviaria líder mundial, pero que prácticamente el país no puede pagar por los costos de mantenimiento, entonces, empiezan a cobrar interés cuestiones como irse a dimensiones elevadas de BIM y decir, bueno, apliquemos por ejemplo sensórica avanzada, porque podemos hacerlo y empecemos a dejar de hacer mantenimiento predictivo, y mantenimiento correctivo vayamos al concepto de mantenimiento condicionado. Podemos sensorizar las redes, tenemos una buena información digital que nos lo soporta, y por lo tanto actuemos ahí donde hay que actuar. Si a esto se le suma algo de inteligencia artificial sin que sea una barbaridad, los beneficios económicos, por ejemplo en obras lineales, son enormes. En edificación, pasa un poco lo mismo. Estamos empezando a ver, porque confluye todo en nuestro país, el advenimiento del empoderamiento de la gente en electricidad, contadores inteligentes, de momento eléctricos, tendrán las de agua también. Esto puede estar coordinado con las instalaciones del edificio. Cuando hay fallos y en las fases de mantenimiento pasa lo mismo. Dónde están las instalaciones del edificio? En edificios antiguos, al final, es un prueba y error. Teniendo una buena definición de las instalaciones dentro de un repositorio digital, hacer una operativa es ir, hacerla y volver, un coste acotado. Hoy, es una aventura, y entonces claro, las aventuras cuestan dinero.

Creo que un poco, este sería el resumen, no? Beneficios, podríamos entrar en más, pero ya se ve que son muchos, sino, muchísimos.

FERNAN: Bueno, centrémonos aquí dentro de lo que es la investigación de la UPC, en materia Bim, hay algún proyecto que le haya llamado la atención que lo haya hecho la UPC?

DON IGNACIO: Bueno, ahora mismo, y esto está bastante dentro del grupo que trabajamos nosotros, mi especialidad es la de prevención de riesgos laborales, pero hemos entendido un poco, que esta es una escuela de ingeniería civil, y que los proyectos de investigación que se hacen aquí en general están en este ámbito. Ha sido una inquietud de las propias constructoras atraer dinero en investigación en materia en general de digitalización. BIM no deja de ser un hermano de la digitalización, o una consecuencia de. Porque sin digitalización tienes muy
difícil cuando todavía estás trabajando con papel físico las obras, viendo planos en la obra, no solamente con instrumentos de este estilo, no. La realidad es otra, no? Haciendo PPIs con control de calidad con papel, llevando las firmas de una carpeta a otra. Bueno, aquí algunas de las cosas que hemos desarrollado por ejemplo es, teniendo en cuenta que tenemos de momento a revit como estándar de las carencias que tienen, tratar de coordinarlos con empresas o constructoras o ingenierías para desarrollar pequeñas aplicaciones para ellos, incluso Apps. Tratando de agarrar las tecnologías que tenemos más o menos cercanas por ejemplo, realidad aumentada con herramientas como ar kits de Microsoft. Bueno, está bastante al alcance de casi cualquiera y esto permite disponer de un modelo tridimensional en un teléfono móvil con facilidad. Llevar esto a la inspección, por ejemplo, de las armaduras de una obra estructural, no es difícil. El interés de la investigación no está tanto en desarrollar la herramienta, que no es realmente complicado, sino en una vez desarrollada, testearla en obra. Y testearla en obra no significa decir vamos a implantarla desde ya, no. Significa que trabajadores que ya tienen una inercia de años porque ya son experimentados, vean que pueden existir nuevos mundos para ellos dentro del trabajo, de su trabajo diario. Porque personas de 30, 40 o 50 años, hay un programa que nosotros trabajamos mucho que es la parte de formación. Cómo introducimos estos conceptos en estos trabajadores? O en técnicos, jefes de obra que llevan 20 años trabajando de una manera determinada y ahora se les dice, si haces esto de esta manera vas a tener grandes beneficios. Bueno, bueno, vamos a ver, yo tengo que hacer mi trabajo, tengo una responsabilidad sobre los resultados económicos de mi obra y cambiaré en la medida que yo disponga del tiempo para hacerlo, en la medida que se me forme correctamente y en la medida en que le vea a poder ser a corto plazo resultados a esto. Esta mezcla, es un poco difícil de hacer llegar el mensaje. Entonces, una manera que nosotros pensamos, y que por ejemplo las empresas de construcción ven con agrado es, ir a mostrar, aunque después les quede lejos y no vaya a ser al día siguiente. Esto lo hemos hecho por ejemplo con una aplicación de programas de puntos de inspección de control de calidad. Decir, oiga, a un encargado de obra, miré, hicimos esta App. Como nosotros creemos que es fácil, pruébela. Entonces agarras una tableta y se la dejas. Entonces el tipo ve que lo mismo que estaba haciendo en un papel y de una forma muy amigable y muy sencilla, tiene ahí el pliego de condiciones del proyecto, tiene ahí el mismo programa diario de las cosas que tenía que revisar, tiene ahí los resultados por ejemplo del hormigón de las probetas. Y con cuatro clicks lleva eso, no ya a su bolsillo para después llevarlo a la caseta, para que después alguien lo pase a un excell, no, no, es automático. Esta automatización motiva porque lo que si ve el tipo es que emplea menos tiempo. Y después hay que enseñarle un concepto que es el de la seguridad. Si a cualquier máquina le introduce los datos incorrectamente, los datos de salida serán incorrectos, es un paradigma de toda la vida. Pero, esto no quiere decir que durante el tránsito digital, al menos la información, tal como estaba, discurre. Por tanto, deja de haber errores en el paso por ejemplo de un documento en papel a un excell, u otros tránsitos semejantes. No? Ya no digo un concepto planos. El concepto planos sigue siendo bastante dramático las versiones de los planos. Las versiones de los planos y las consecuencias que tiene hacer cambios sobre ellas en otras partes de la obra. Mientras se está haciendo la estructura, nadie piensa en qué pasa con las instalaciones. Hacemos muchas veces cambios de forma indiscriminada en elementos estructurales y después, una cosa que en
principio revit por ejemplo sí permite que es el estudio de las colisiones, nos las encontremos en la obra. Aún no tenemos la conciencia del adelantarnos al problema y de hacer el trabajo directamente. Pues este es el punto en el que estamos, no? Investigar significa para nosotros generarles expectativas, un poco más allá de su día a día. Y a partir de ahí, motivarles. Si no motivamos al sector, no empatarán nada. Si, un día, pero dentro de 10 años, pero lo queremos ya.

FERNAN: Por qué cree que a España le cuesta tanto moverse con la tecnología y entrar en esta digitalización que es inevitable? Es un poco personal, pero quiero saber qué piensa usted, por qué países como usted está diciendo, el Reino Unido, por qué ellos ya lo han conseguido desde hace mucho tiempo y por qué España...

DON IGNACIO: Claro, yo tengo 25 años de carrera profesional, como ingeniero en mi país. De éstos, solo los 5 últimos los dediqué a investigar. Fui ingeniero de obra durante 20, y ahí me he dado cuenta de cuáles son nuestras dificultades. Las principales, en realidad no es tanto lo último que comenté, sino lo anterior; es la formación. Nosotros seguimos arrastrando una mala formación de base de los trabajadores. En esto, por ejemplo, si me voy a mi máximo campo de especialización que es la prevención de riesgos laborales, es una formación que ahora mismo estamos proyectándonos en el ámbito pedagógico también en países como Reino Unido, una vez más, por qué? Porque están enseñando relación de riesgos a los niños en el colegio; o les están enseñando educación vial. Pero, caramba, aquí nos llenamos la boca de decir que les enseñamos educación vial a los niños, y eso no es que un día venga un representante de la policía a ponerte una película y a hacerte un juego. No, eso hay que hacerlo de una forma un poquitín más reglada y severa. Y es tan sencillo, como si uno se propone a hacerlo, de generar un libro blanco sobre eso, generar debate, y después hacer unos protocolos bien hechos para que esa pedagogía, sea para niños o sea para adultos, sea de verdad efectiva. Con el cinturón de seguridad, aquí pasó lo mismo. Tardamos entre 10 o 15 años, entre que existiese la obligación legal y se pudiese llevar a la práctica sanciones sobre eso. Porque nadie lo hacía, hubiésemos tenido que sancionar a todos. Bueno, hubo momentos en los que eso sí se hizo, pero, cuándo realmente eso es efectivo? Cuando la persona toma conciencia, como me puede pasar a mí ahora, de que si entra en su vehículo, no tiene ningún sentido arrancarlo si no tiene el cinturón de seguridad puesto. Lo mismo pasa en prevención, lo mismo pasa en digitalización, y lo mismo pasa en todo. Que tenemos esta característica, vamos a decir, muy latina y mediterránea nuestra de dejar que las cosas sigan su curso. Sí, es así, pero es multisectorial, y desde mi punto de vista, las generaciones siguientes, quizás gracias a la invasión tecnológica, van a vivir esto de otra forma, y se llevará a otros puntos, como a la política y otras cuestiones, y el país saldrá.

FERNAN: don Ignacio, ya que usted ha trabajado en esto, qué software ha experimentado y con cuál ha sido su mejor opinión?

DON IGNACIO: Bueno, nosotros aquí hemos trabajado básicamente con los más estándares, por un motivo muy claro, porque se nos acercan muchas gentes diferentes de toda la construcción. Un día es la administración, u otro día es otro día es un estructural, otro, otro profesional. Entonces, en vez de utilizar revit utilizamos robot, por dar un ejemplo, aunque pueda, a mi me suscita el interés de que robot es un programa muy potente para trabajar con
estructuras y por lo tanto es más que probable que la coordinación ahí esté muy bien hecha. En cambio en revit esto no es así, hay que inventarlo, hay que hacerlo, o hay que ir a buscar links con otras cosas. Sí, pero es que resulta que se estableció revit. Entonces, revit, navisworks, o ar kits para la parte de realidad aumentada, no estamos moviéndonos mucho de estas aplicaciones básicas. El resto lo hacemos programando nuestro propio código, porque simplemente son ejemplos para que los profesionales vean posibilidades que no sean comerciales. Después les invitamos a que hagan sus propias búsquedas; para eso están los departamentos de innovación de las empresas. Pero hay un gap entre esos departamentos de innovación y los trabajadores. Esto se ve claramente porque nosotros, que desde aquí tenemos una influencia relativamente pequeña en el sector, estamos trabajando con algunas empresas solamente. Entonces vienen mis estudiantes y me dicen, por ejemplo en grado, por qué no nos dáis información sobre BIM; y les digo, es que no está en el programa. Empecé a trabajar en una empresa y me piden que sepa de esto. Estamos hablando de los ingenieros civiles que estamos formando en 2018 y que van a acabar entre 2018 y 2019, y la ley dice que eso va a ser obligatorio en 2019, ¿qué sentido tiene? Aquí falla algo. No hay un gap, hay muchos gaps. ¿Qué pasa con esto? Entonces volviendo a las herramientas, mejor intentamos que todo mundo domine una al menos, y ya avanzaremos después. Claro, yo he visto en algunas webs algunos desarrollos netamente comerciales impresionantes. Pero me parece impensable que, salvo que haya un acuerdo tácito entre por ejemplo, una administración, un gabinete de proyecto, una empresa de project management y una empresa constructora, si es que la hay, o los subcontractistas, para optimizar aquello. En este caso en particular pues porque interesa, pues a lo mejor porque es una obra singular, por la difusión que se le quiere hacer. Si no se hace de esa forma, ahora mismo intentar utilizar herramientas un poco avanzadas, bueno, también lo dejo a la voluntad de los técnicos que tienen más interés. Pero se encontrarán las mismas dificultades, o avanzamos todos juntos, o sea, por lo tanto aquí utilizamos lo más estándar.

FERNAN: Ha escuchado usted de casos de una dirección facultativa o de obra utilizar programas de Bim para diseñar un proyecto? En cuyo caso sí es sí, cuáles?

DON IGNACIO: Cómo respondería a esta pregunta sin resultar ofensivos para nosotros mismos. A mí los arquitectos me llegan a decir: “Vaya, ahora tenemos que cambiar de forma de trabajar”. Los arquitectos en España tienen también otro defecto añadido, que es a su vez una ventaja. Particularmente en Barcelona, Barcelona tiene 2 escuelas de arquitectura. Generamos arquitectos formalmente, es decir, en el ámbito del diseño formal, muy talentosos, apreciados incluso en todo el mundo. Pero solamente ahí, porque después la parte estructural, la parte de instalaciones de edificios, simplemente otros asumen que otro va a resolverla. Entonces, claro, al final, la dirección de obras, más allá de la figura del técnico intermedio, que se encarga sobre todo de la parte de ejecución, tiene la firma de un arquitecto en el caso de la edificación. En el caso de la ingeniería civil es diferente. En ese caso yo estoy viendo que ya son las grandes ingenierías, por lo menos, las pequeñas también bastante, pero las grandes ingenierías ya están adoptando los sistemas. La dificultad está en que, por ejemplo, en esta herramienta estándar las obras lineales no son fáciles de implementar. Bueno, pero ya sé que ahí están, que es un buen programa de carreteras, y puede exportar bien datos a revit. Lo que pasa es que después cómo tratamos eso, como objetos, cómo se define, no está claro. El
el instituto de tecnología de la construcción de Cataluña que es la fundación privada sin fines de lucro que tenemos aquí, compartida con la administración y las empresas consultoras e ingenieras en general, y es la que custodia la base de datos de precios oficial, está haciendo un esfuerzo importante para hacer llegar esta cultura a todas las empresas. Donde está teniendo éxito es en la obra civil, pero revit no se creó específicamente para obra civil, por lo tanto, ellos se encuentran con el mismo problema que nosotros. Si no están de momento en el ámbito de lo estándar, generarán una dificultad a nadie más. Por lo tanto estamos en un momento de impas. Yo creo que lo que ocurrirá es que en una, dos, o tres generaciones más, a partir del año que viene por ejemplo, ya vamos con formación reglada en grado para los estudiantes. Va a ser las nuevas generaciones las que van, y además, los profesionales no lo piden. Tú me preguntabas, conocen de casos? Bueno, los casos que conozco son los de estudiantes que vienen aquí a pedirme que sepan de eso para implementarlo en sus empresas. Bueno, al menos es un primer caso. Yo tengo que comprender a mis compañeros. Ellos están con responsabilidades importantes; la dirección de obra es una responsabilidad importante. Y por lo tanto, están acostumbrados a unos protocolos, trabajan de una determinada forma, y han sido muy cuidadosos de creer a ciegas en algo que todavía no entienden bien. Y a qué formación pueden aspirar? Hoy un ingeniero de caminos puede estar llevando 2 o 3 obras a la vez de relativa importancia y el tiempo es escaso. Bueno, por lo tanto tengo que responder más no que sí a la pregunta, pero sí es cierto que tenemos muchas consultas a nivel de escuela, a nivel de centro, de los profesionales, diciendo: “Estáis formando a los chicos en esto? Porque les necesitaremos”. Bueno, para mí es suficiente porque es cierto que si los chicos salen, que además son niveles, es decir, para ellos la digitalización está en sus genes, no en los míos, yo he tenido que adaptarme a todo esto también. Yo creo que el futuro lo tenemos asegurado, pero no a corto plazo.

No sé si contesté del todo a tu pregunta, es que era del todo escabrosa en cierta manera. Tengo que tirar piedras contra nosotros mismos, pero tengo que ser sensible a las preocupaciones, porque no es solamente BIM lo que entra para ellos. Por ejemplo, drones. Caramba, si es que hay unos cuantos ingenieros que se han preocupado por ese tema. Lo están utilizando en inspecciones de obras exitosamente, peleándose con la normativa que todavía no está preparada, y bueno, no está mal. Hay gente que está haciendo mucho esfuerzo para muchas cosas.

FERNAN: Tengo una última pregunta. Cree que vale la pena para una dirección de obra implementar software con aplicaciones BIM para administrar mejor una obra? Y en cuyo caso, qué softwares utilizaría usted hoy en día en España para gestionar una obra, como dirección de obra?

DON IGNACIO: Yo centraría ahora los esfuerzos en la planificación, a nivel de la obra, en la planificación. Porque es donde más, en mis años de experiencia a pie de construcción, donde he visto sufrir más a todos los agentes. En primer lugar, porque tenemos una muy mala costumbre aquí que es la de rectificar los proyectos antes de las obras. No por matices que a veces el terreno, por ejemplo, puede darte una sorpresa no prevista y entonces, vale, hay que modificarlo. No, es que aquí tenemos la exquisita costumbre de licitar a un precio, para tratar
de conseguir otro posteriormente. Esto es cambiar los proyectos. Vamos, en otros países esto es impensable; no existe, ni existirá.

Entonces, a eso, que va ligado directamente ligado a la planificación porque las obras se cambian, los caminos críticos cambian, los precios cambian, hay que revisarlos. Yo creo que un primer esfuerzo, que además serviría a lo mejor, ligado aún con el concepto de in construction, no creo demasiado en él. Pero el de last plan por ejemplo me gusta más, porque sitúa al técnico y lo enfrenta directamente a la planificación, pero con la vista puesta en que aquello que haga sobre la planificación o que vaya a ocurrir sobre ella, va a tener incidencia en todo lo demás. Si tuviese de decidir por dónde empezar a incidir más, es ahí, porque es que todos los agentes entran y todos los conceptos se resienten. El plan de seguridad depende de la planificación; el control de calidad depende de la planificación; y por supuesto, la economía de la obra, tras de todos, depende de la planificación. Porque obviamente la economía que la administración tiene que poner a disposición, por lo tanto, es un elemento clave. Y no está bien resuelto todavía, o por lo menos no lo tenemos bien resuelto aquí, el hecho que si hacemos mucha planificación con Microsoft project. Bien, cambiar cosas ahí es muy fácil y el project lo aguanta todo. Pero si un cambio ahí resultase en 25 alarmas, algunas de las cuales fuesen relevantes porque la arquitectura con la que estás trabajando la informática te dice: “Escucha, cuidado con lo que estás acordando en esta reunión en la que estamos todos porque va a pasar esto, va a pasar lo otro, y su repercusión económica es tantas decenas de miles de euros.” Entonces la cosa cambia, ahora no tenemos esta perspectiva. Ahora cambiar cualquier cuestión se decide, y después se ven las consecuencias, no las puedes ver en ese momento. Desde todos los puntos de vista, pero es un poco el final de toda la cadena a nivel de obra. Fijaos que hemos hablado básicamente solo el principio de las ventajas que BIM tiene, que yo las veo de verdad en el campo del mantenimiento. No solo nuestro país sino muchos que ahorrarán cientos de millones de euros o de dólares, esto será así. Pero la fase de obra es crítica. Es crítica porque hay una gran concentración de esfuerzo allí. Entonces, si conseguimos que se tome conciencia de que actuar sobre la planificación tiene consecuencias, creo que podemos dar un paso de gigante. Me parece que la forma sería un poco terapia de choque. Si vamos a ser exigentes con saber qué consecuencias tiene cada una de las cosas que hacemos sobre la planificación prevista, hay una naturalmente. Evidentemente, hay un momento de muy bajas temperaturas y no podemos hormigonar, si eso es inherente a nuestra forma de trabajar. Y habrá incidencias, pero no puede haber incidencias caprichosas, en el sentido de decir, como ahora quiero que me cambies el precio, voy a hacerte un chantaje y voy a correr esta actividad, hasta que consiga mi objetivo.

No, eso no puede ser. Eso hay que saber en el momento, por ejemplo, para que el director de obra o el representante del promotor tome una decisión, que a lo mejor puede ser comitiva para con el constructor, si esto tiene que ser así. O al revés, porque todos los agentes tienen que estar en igualdad de condiciones. Evidentemente, unos tienen responsabilidades sobre otros, pero si basamos, que esta es una opinión, y vamos ahora a hacer un trabajo sobre esto, una estudiante de máster en su tesis. Creo que el hecho de tener la planificación controlada y linkeada con el resto de documentos del proyecto digitales, y si no se quiere con todos por lo menos con los principales: con los planos, con el control de calidad, con la prevención de riesgos, con el
presupuesto, fundamental. Sería al principio, una terapia de choque, llena de incidencias, pero este acostumbrarse a que cada vez fuesen menos, sería lo que allanaría el camino a la implantación quizá de la obra social. Me he formado esta opinión no hace mucho pero pensando en las cosas que veo.

FERNAN: Adónde cree que vamos con el BIM? Y cuál es su visión a los 5, 10 y 20 años?

DON IGNACIO: Yo esperaría de mis compañeros y de mi sector, por decirlo así, empezando por la de en medio, es el término del orden de los 10 años estuviésemos trabajando con mantenimiento acondicionado en general en las obras. Esto porque además ya hay unas cuantas empresas importantes en España que están haciendo trabajos por ejemplo de reconstrucción de edificios antiguos o de redes lineales de ferrocarril, metro, etc., para llevarlas a programas BIM. Esto con tecnología láser etcétera y después con un poquito de trabajo sobre objetos, se puede hacer. Bueno, poniendo un poquito de inversión en eso, en las partes más importantes del parque de edificios que tenemos, por ejemplo los públicos, de infraestructuras que tenemos. Porque ahora estamos construyendo poco y hay que aprovechar este momento. Estamos construyendo poco porque hicimos un gran esfuerzo de ventas en el país. Yo apostaría a 10 años vista por estar en los principios del mantenimiento acondicionado, mantenimiento a tiempo real. A 5 años vista, esperaría que estos conceptos de los que hablaba que ya no hubiese ninguna duda de que trabajamos coordinadamente presupuesto, planificación y los conceptos básicos de construcción digitalmente en obra estuviesen resueltos, por lo menos en edificación. Y puede que sea al revés, porque en el fondo el número de partidas de obra en obra civil es menor.

Por tanto, a veces pensamos que la edificación está muy bien ordenada y es mucho más fácil porque el ámbito, pero no, la edificación es compleja, es extremadamente compleja. Creo que a 5 años vista podríamos esperar eso, y a 20 no sé qué puede pasar. Porque entre otras cosas yo debería estar jubilado…

FERNAN: El ámbito público o en el ámbito privado en general?

DON IGNACIO: El ámbito privado supera siempre al público, siempre. Es que es una realidad; es quien se juega el dinero no de un contribuyente, sino de un fondo privado. Por lo tanto, yo de esto sí, no tengo duda. Lo que pasa es que en el ámbito de las infraestructuras aplica poco, porque son muy grandes. Pero en el ámbito de la edificación llevarán adelante esto, y ahora no es mal momento, porque tenemos un re arranque del sector inmobiliario. Llevarán adelante esto las promotoras privadas, por interés económico. Porque este 2% del que hablaba de repasos finales de obra en obras de edificación, es un montón de dinero. Pagas con ello 10 técnicos trabajando en un edificio, en un edificio grande, a lo mejor de 100 viviendas, por ejemplo. Estamos hablando a lo mejor de un millón de euros, entonces el esfuerzo vale la pena. Entonces qué nos queda? La formación, de nuevo la formación. No hay todavía gente suficiente. Pero, ese es un esfuerzo que estamos haciendo desde aquí también. La investigación nuestra, en parte, motiva a los chicos a venir a hacer trabajos de este estilo. Nos ayudan y salen de aquí sabiendo muchas cosas que aprenden ellos. No se dan cuenta que al final si todo mundo decidiese agarrar los títulos de los tutoriales que hay en internet, sabrían de BIM en 3 días. Pero no puedo pedirle eso a mucha gente, ni yo ni vosotros, probablemente.

Ahora os voy a hacer yo una pregunta. Qué ocurre en vuestros países, cómo andáis con BIM?
FERNAN: Yo en Costa Rica honestamente, no estoy muy seguro porque yo nunca he trabajado en mi país. Entonces no, pero no creo que esté muy adelantado porque por lo general Costa Rica siempre está un poco por detrás de los anglosajones. Entonces supongo tampoco está muy implementado, pero sería bonito que algún día yo pueda llevarlo allí.

DON IGNACIO: Tenéis un reto interesante por delante, o adquirís en Europa un conocimiento que después os puede llevar a tener un valor añadido en ciertos sitios.

FERNAN: Claro. Bueno, muchísimos gracias por su tiempo don Ignacio. Espero que hayan aprendido muchísimo con nosotros hoy en aplicación de BIM en construction management, y un poco de la visión de alguien que es un experto en su ámbito.

Muchísimas gracias por estar con nosotros.
The author is currently responsible for imparting BIM 360 Lessons on his company. Based on his background on the subject and his due diligences invested on both of the software mentioned throughout the thesis paper, he was told that it would serve the company hugely if he could somehow create quick 30-minute modules on the main topics comprised by BIM 360. These modules were to include the entire life-cycle of the project from its conception with Autodesk Revit or similar modelling software all the way to its importing to BIM 360 Glue and eventually BIM 360 Field. The following Excel displays the modules the Author created and submitted so that any user in his company can learn about the software and use these videos both as a guiding manual and as a tutorial.

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Ya completado
Desarrollándose
Técnicas Experimentales de Caracterización de Materiales de Construcción

Técnicas Experimentales-Sonómetro

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RESUMEN

El proyecto se basó en desarrollar un sonómetro utilizando un sensor de sonido FC-04 y la placa Arduino UNO. El objetivo proyectado era desarrollar un dispositivo de detección de sonido para presentar mediciones calibradas en decibéles. La aplicación del proyecto se proyecta a mediciones en obra en donde se pueda hacer una comparativa de los valores obtenidos al utilizar un sonómetro oficial y certificado versus el desarrollado, a fin de evaluar la precisión de éste. La visualización de los resultados se realiza a través de una pantalla LCD1602, en donde se presentan los valores medidos en decibelios, tomando en cuenta las calibraciones, las cuales están inmersas en el código de programación en Arduino empleando métodos de regresión lineal. El sonómetro se coloca adentro de una caja de madera customizada para que semeje el original y resulta tener limitaciones de mediciones, pero cumple su objetivo dentro del rango de 47-73 dB.

Palabras clave: sonómetro, presión sonora, sensor de sonido, Arduino, IOT.

1. INTRODUCCIÓN

El trabajo consiste en crear un dispositivo económicamente factible que permita aumentar la seguridad de los trabajadores a pie de obra. EN aparato que mide el nivel de presión sonora puede aumentar la salud y bienestar de los trabajadores involucrados en la obra y además potenciar que la alteración de la vida cotidiana del vecindario sea mínima.

El proyecto se basa en un dispositivo que ya existe y que se utiliza en obra pública y privada denominado sonómetro. Un sonómetro tiene como meta medir el nivel de ruido que existe en determinado lugar y en un momento dado. Los sonómetros se pueden clasificar por tipología de uso y precisión, el desarrollado en esta clase es proyectado en ser un sonómetro de clase 1: permite el trabajo de campo con precisión.

Los sonómetros suelen disponer de un interruptor de rango que permite elegir un rango dinámico de amplitudes específico con el objetivo de obtener una buena relación señal-ruido en la lectura. Las posiciones habituales de los rangos son las siguientes tres posiciones: 20-80 dB, 50-110 dB o 80-140 dB. Para un sonómetro de clase 1, el rango más común es el que va de 50-110 dB puesto que esto incluyen los niveles de una conversación normal efectuada en obra hasta algún equipo liviano siendo empleado. La Figura 1 ilustra los niveles de presión sonora en decibelios y ejemplos de casos concretos del día a día.

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El prototipo se desarrollará empleando un sensor de ruido FC-04, el cual transforma una magnitud del mundo físico a una señal eléctrica, un sistema de adquisición de datos Arduino, el cual transforma dicha señal eléctrica en valores numéricos que puedan ser procesados para posteriormente presentarse en un actuator LCD en donde se mostrará el nivel de ruido en decibelios.

Fig 1: Nivel de presión sonora y ejemplos.

En Cataluña, la contaminación acústica queda regulada por la Ley 16/2002, de 28 de junio, de protección contra la contaminación acústica, y su despliegue reglamentario, el Decreto 245/2005, de 8 de noviembre, por el que se fijan los criterios para la elaboración de los mapas de capacidad acústica, y el Decreto 176/2009, de 10 de noviembre, por el que se aprueba el Reglamento de la Ley 16/2002, y se adaptan sus anexos. Se adjunta en el Anexo I las partes más importantes en términos de contaminación acústica que promueve la utilización del sonómetro.

2. SISTEMA DE MEDICIÓN

El hardware empleado para la medición se muestra en las Figuras 2 y 4. Cada elemento se describe a continuación:

- Protoboard
- Arduino UNO
- Sensor de ruido FC-04
- Actuador LCD1602A

Fig 2: Protoboard, Arduino UNO, sensor de ruido FC-04.

2.1. Protoboard

Permite transmitir el voltaje entre los sensores, la placa arduino y los actuadores. Los canales extremos (positivo + y negativo -) transmiten la energía verticalmente y los canales internos lo hacen de manera horizontal. En la protoboard es donde se conectará el sensor de sonido y las resistencias para obtener su buen funcionamiento.

2.2. ARDUINO UNO

El sistema de adquisición de datos empleado para el procesamiento de las mediciones con el FC-04 es la placa Arduino Uno, la cual contiene el microcontrolador ATmega328 de 10 bits, que trabaja con tensiones entre 0 y 5 V. Las lecturas analógicas tendrán entonces valores entre 0 y 1023 (210), por lo que los valores de diferencia de potencial medidos tendrán incrementos a razón de 0.0048828125 V, es decir, 4.8 mV (Resolución). Al ser un microcontrolador un sistema digital, y el nivel de sonido una magnitud analógica, es necesario un sistema que pase de analógico a digital; Arduino Uno posee un ADC (Analog digital converter). La frecuencia de adquisición de datos es de 8 928 ciclos por segundo ó 8.928 kHz, por lo que no se podrá obtener mediciones en intervalos de tiempo menores.

2.3. Sensor de ruido FC-04

Este sensor es de entrada analógica (los valores a medir son provenientes de la realidad y por tanto su valor es analógico) y una salida digital. El sensor es una pequeña placa de circuito que lleva instalado un microfono, un chip LM393 y otros componentes electrónicos. Se alimenta con una tensión entre 2.7-5.5 V y consume 1.4 mA de corriente. La
temperatura de funcionamiento está entre -30 °C – + 85 °C. Sus dimensiones de largo, ancho y alto son: 47 x 18.4 x 10 mm respectivamente. El sensor de sonido está equipado con un conector de pin macho especial para la conexión a la tarjeta de microcontrolador ARDUINO. La Figura 3 ilustra el funcionamiento del sensor.

![Fig. 3. Esquema de funcionamiento del sensor de ruido.](image)

2.4. Actuador LCD1602A

Se utilizó un actuador LCD1602A (Figura 4), el cual puede mostrar 2 líneas de 16 caracteres, en donde se mostrará el valor del sonido medido mediante el sensor y el procesamiento de datos.

![Fig. 4. Actuador LCD1602A.](image)

La programación en ARDUINO para el funcionamiento la pantalla se realiza llamando a la librería LiquidCrystal. Debido a la sensibilidad limitada del sensor FC-04 se estableció una condición límite para que en caso del sonido sobrepasar el rango de trabajo analógico del sensor se muestre el mensaje “ERROR” en la pantalla, caso contrario se mostrará el valor medido.

3. ENSAME DEL DISPOSITIVO

Se explicará la conexión de cada dispositivo a la protoboard y al Arduino. El sensor FC-04 se conecta a los canales positivo y negativo en sus pines Vcc y Gnd respectivamente, el pin Out se conecta directamente a una entrada analógica del Arduino (A1 en este caso). La conexión virtual con el pin Vcc del sensor tendrá una resistencia de 330 ohms. Las resistencias se instalaron para mejorar la sensibilidad del sensor puesto que la salida de este es digital, por lo que el rango de valores obtenidos en las mediciones tenía un techo a partir del cual adoptaba un valor máximo; con estas resistencias se logró aumentar el rango de resultados previo al salto al valor máximo, el cual no se pudo eliminar dada la naturaleza digital de la salida del sensor; es decir, el sensor utilizado está pensado para medir la existencia o no de ruido mas no un nivel exacto de cantidad de ruido a lo que llamarnos decibel (dB).

La pantalla LCD se conecta a los diferentes pines de Arduino y de la protoboard, se explica la conexión en la Tabla 1:

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<td>- (GND)</td>
</tr>
<tr>
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<td>+</td>
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<tr>
<td>A</td>
<td></td>
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<tr>
<td>R</td>
<td></td>
<td>-</td>
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<tr>
<td>Potenciómetro -</td>
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<td>-</td>
</tr>
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<td>+</td>
</tr>
<tr>
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<td></td>
</tr>
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<td>D4</td>
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<td>11</td>
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</tr>
<tr>
<td>D7</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>V0</td>
<td>CENTRO POTENCIO -</td>
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</tr>
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</table>

4. PROGRAMACIÓN EN ARDUINO Y CALibrACIÓN

El código de programación, en donde está inmersa la calibración para presentar las mediciones en decibels se explicará a continuación:

```c
#include <LiquidCrystal.h>
LiquidCrystal lcd(7, 8, 9, 10, 11, 12);
```

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Al ser el sonido una magnitud analógica que tiene duración instantánea y que puede presentar variaciones en espacios pequeños de tiempo, se define en la programación una ventana (llámese también intervalo auxiliar) de muestreo igual a 50 milisegundos, equivalente a una frecuencia de 20 veces por segundo o 20Hz, por lo que el valor representativo de ese intervalo será el promedio de mediciones dentro de ese intervalo; al ser el delay programado igual a 10 ms, cada ventana de 20 Hz tendrá 5 valores leídos para obtener un promedio. Se define las variables simpleWindow (ventana de muestreo), sample (valor leído del puerto analógico al cual está conectado el sensor), limite (valor límite de precisión del sensor, obtenido mediante la calibración que se explica más adelante), dB (variable que almacenará el valor calculado de decibelios).

```c
const int sampleWindow = 50; // Sample window width in ms (50 ms = 20Hz)
unsigned int sample;
const int limite = 73;
double dB;
void setup()
{
  Serial.begin(9600);
lcd.begin(16,2);
lcd.print("Sonido (dB)");
lcd.setCursor(0,1);
}
void loop()
{
  unsigned long startMillis = millis(); // Start of sample window
  unsigned int peakToPeak = 0; // peak-to-peak level
  unsigned int signalMax = 0;
  unsigned int signalMin = 1023;

  // collect data for 50 ms
  while ((millis() - startMillis < sampleWindow)
  {
    sample = analogRead(A1); // sample
    if (signalMax < sample) // save just the max levels
      signalMax = sample;
    else if (signalMin > sample) // save just the min levels
      signalMin = sample;
  }
  peakToPeak = signalMax - signalMin; // max - min = peak-peak amplitude
  double volts = (peakToPeak * 5.0) / 500; // convert to volts
}
```

Ahora se explicará la calibración y cómo se transforma el valor de voltaje en valores de decibelios. El nivel de ruido medido en decibelios no es proporcional al incremento del valor medido de voltaje, por lo cual para obtener una ecuación que permita el cálculo de la presión sonora se realizó una calibración, la cual consistió en realizar varias mediciones en las que se comparan los resultados de voltajes medidos con arduino versus valores en decibelios obtenidos mediante diferentes dispositivos independientes en distintos instantes de tiempo. La curva obtenida se muestra en las Figuras 5 y 6.

**Fig 5. Calibración con regresión lineal.**

**Fig 6. Ajuste de tendencia con curva polinómica.**

En la Figura 6 se aprecia a simple vista que agregando una curva de tendencia polinómica se puede aproximar bastante bien el cálculo de los decibelios a partir de los valores de tensión medidos con el sensor, pero se decidió calcular el valor de decibelios mediante la ecuación de la recta de regresión lineal obtenida mostrada en la Figura 6 debido a la compatibilidad de programación de operaciones dentro del software de Arduino. Despejando el valor de x de la ecuación mostrada en la Figura 6 se obtiene la ecuación de cálculo de decibelios:

$$dB = \frac{y + 1455.6}{31.43^3}$$  \hspace{1cm} (1)
donde y es el valor de voltaje (volts) medido multiplicado por 1000; se multiplica esta cifra para obtener mayor cantidad de cifras significativas para la calibración, puesto que el SerialMonitor presenta valores con dos cifras decimales. Finalmente se programa el actuador LCD para mostrar el valor calculado de voltaje o un mensaje de "Error" en caso de que la medición sobrepase el valor de 73, puesto que en este valor el sensor alcanza su máxima sensibilidad y se dispara el resultado. El resto del código se muestra a continuación.

```
float volts = (volts * 1000) + 0.44 / 1.23;

if (volts > 73) {
  lcd_print("ERROR");
  lcd.setCursor(0, 2);
} else if (volts < 73) {
  lcd_print(vols);
  lcd.setCursor(0, 2);
}
```

Se debe añadir que la calibración del sensor toma en cuenta que el rango de trabajo queda definido entre 47 y 73 decibeles; la figura 7 permitirá explicar la obtención del valor mínimo aceptado para la medición:

![Fig 7: Tensión vs Decibeles tomando en cuenta valores menores a 47 decibeles.](image)

Se observa que para obtener valores menores a 47 decibeles con una confiabilidad aceptable, empleando la ecuación de regresión lineal propuesta, las lecturas de tensión deberían tomar valores negativos, lo cual no es posible en este caso. La situación es similar para el escenario de una curva de tendencia polinómica.

### 5. APLICACIONES A LA INGENIERÍA

La aplicación de un sonómetro en ingeniería civil arraiga su importancia en España puesto que en la actualidad, España junto a Japón son los países con mayor índice de población expuesta a altos niveles de ruido. Casi 9.000.000 de españoles, soportan niveles medios superiores a 65 dB[1]. La contaminación acústica y los aspectos medioambientales de una obra de construcción están en el foco de mira de la sociedad puesto que la gente tiene la percepción de que la industria en su conjunto y solo del interés de ayudar al ambiente. Ya sea el ejemplo de que ven los camiones, repletos de Ruma y asumen que todo va a vertederos o que se deposita el agua de la obra en embalses. La industria genera cierta miedo y de angustia y la legislación quiere asegurarse de que todos estos temas "verdes" están siendo controlados con medidas cada vez más meticulosas.

En el caso del trabajo que se ha concebido para la clase de técnicas avanzadas experimentales de la construcción, uno de los integrantes del grupo trabaja como dirección de obra en una obra pública cuyos clientes, concesionaria e indirectamente Generalitat de Catalunya, que unigen que se hagan torres de niveles de sonido en puntos críticos de las estaciones mensualmente. La constructora ha de hacer estas medidas de niveles de presión sonora con la presencia de la dirección de obra y toda esta información viene presentada en el informe mensual de calidad de la constructora. El documento tiene que venir firmado por el responsable de calidad de la constructora y de la dirección de obra. En el Anexo 3 se reseña un ejemplo de estos informes de sonometría.

La idea del grupo de trabajo era crear un dispositivo económicamente ligero y preciso que se pudiera llevar a obra a hacer contraste de los resultados obtenidos por la constructora en los diversos puntos de medición. El sonómetro viene a ser un aparato que es importante para la sociedad porque más allá de proteger a los trabajadores que están expuestos a estos altos niveles de ruido a pie de obra, también deja
prever cuáles trabajos son los que más afectan a
el vecindario y edificios colindantes a la obra.

6. DIFICULTADES Y
RECOMENDACIONES

Las dificultades encontradas a través de
la ejecución del trabajo surgen más que todo por
el hecho de que el dispositivo FC-04 no nos
permite llevar a cabo el objetivo principal del
grupo de trabajo. El objetivo del grupo era crear
un sonómetro que permitiera hacer un contraste
al dispositivo real utilizado por la constructora
pero el dispositivo creado para esta clase sólo
recibe señales adentro de un límite de dB que no
es útil a pie de obra. En obra, por lo general, se
están buscando actividades que lleguen a
supercasar los 80 dB y puedan ser dañinas para
los trabajadores; el sonómetro de la clase sólo
llega a los 73 dB así que no se podría concluir si
existe una infracción en una actividad.

Al finalizar el sonómetro artesano, el
grupo piensa que se le podrían crear muchos
"features" que vengan a complementar lo que es
la toma de niveles de presión sonora. Hoy en
da, las mediciones hechas con el sonómetro
oficial de la constructora, certificado por
laboratorio cuya vigencia de calibración expira
cada año (Anexo 4), se hacen en planos a papel
y después se llevan al ordenador a través de Excel
y con muy poca automatización. El grupo
piensa que se podría implementar un servicio de
nube que permita que la toma de datos
inmediatamente se conecte con algún software
que cree las tablas necesarias para ir
automatizando un proceso que tarda bastante
Tiempo. Se ha de mencionar que cada tomar de
la medición de 1 punto tarda 1 minuto y en
la obra se tienen 9 puntos. Ahora se le suma el
hecho de que se están trabajando 4 estaciones
simultáneamente, se pueden hacer la idea del
tiempo que se tarda haciendo la rejuntada de las
sonometras.

El grupo también piensa que se podrían
añadir unas luces de LED de estilo semáforo y
así el usuario podría tener idea del nivel de dB
de una manera muy visual. Lo ideal sería que se
pueda escoger el programa que se va a utilizar
para hacer la medición (clase 1 para obra de
construcción) y que el sonómetro se iluminase
dependiendo de los niveles de emisión de ruido
dado momento.

7. REFERENCIAS

projects/arduino-sound-level-measurement
al-conectando-una-pantalla-led.html
Proyectos. ARDUINO. 2013
_ruido.pdf
http://elcosh.org/document/1702/d090020/advertenci
a-de-peligros-33-f-ruído-en-la-construcción%3F.html
20976
http://www.diba.cat/documents/63810/50804/1xarxias
ost-pdf/ordenancascrolloymodelo-pdf.pdf

Máster de Ingeniería Estructural y de la Construcción. 2017-2018
Testigo #1 Planta -2 Escalas de emergencia Costat Mar
Testigo #2 Planta -3 Escalas de emergencia Costat Mar
Testigo #3 Planta -3 Escalas de emergencia Costat Mar
Testigo #4 Planta -3.5 Escalas de emergencia Costat Mar

Testigo #5 Planta -4 Escalas de emergencia Costat Mar
Testigo #6 Planta -4.5 Escalas de emergencia Costat Mar
Testigo #7 Planta -4.5 Escalas de emergencia Costat Mar

Testigo #8 Planta -4.5 Escalas de emergencia Costat Mar
Testigo #9 Planta -5.5 Escalas de emergencia Costat Mar
ANNEX 5 Word Document with Recommendations for BIM 360 (Original Language)

Notas FOC L9 usando BIM 360

- BIM 360 Add-in de Revit no está exportando el modelo al Glue correctamente
  - No sabemos si es culpa nuestra o del software
- La forma en que el proyecto esté concebido en el Revit determina absolutamente todo, una mala estructura de vistas y elementos en Revit arruinan la posibilidad de poder hacer un correcto seguimiento en BIM 360 Field y de hecho que también Synchro Pro
- Cuando he exportado las locations en formato Excel (puesto que quería hacer modificaciones y no tenía el documento original), me ha salido un Excel muy mal hecho. Se adjunta una foto abajo para apreciar mejor el problema.

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**Figura 1: Data exportada con la herramienta de exportar ubicaciones BIM 360 Field**

- BIM 360 File Importer no funciona en mi ordenador (que es un poco antiguo) (en el pasado ordenador sí funcionaba) y no puedo descargar mi estructura de carpetas lo cual dificulta la tarea por mil.
  - El programa no se puede instalar ni por internet ni en ningún lugar de Autodesk, si no corre a la hora de tratar de importar los archivos, es game over.
A la hora de crear un checklist, hay que tener mucho cuidado de que la opción de auto-generate issues está pulsada. De la otra manera, a la hora de que uno pulse incorrecto (o no, o fail, etc.) no se genera un issue y queda en el expediente.

- Se adjunta una foto para demostrar adónde es que se haría esta faena.

**Figura 2: Adentro de Project Admin y Checklists, se pulsa el botón de Editar**

**Figura 3: Botón responsable para que se creen Issues con el checklist específico**

- Para hacer un checklist bien bien hecho, incluyendo columnas como “default answers”, se necesita un esfuerzo grupal intenso que no estoy seguro que lo valga. Se necesita un grado de conocimiento del tema elevado.
• A la hora de importar un checklist con modificaciones, hay que tener mucho cuidado puesto que el programa lo que hace es machacar los dos checklists (antiguo y el modificado) y convertirlos en uno. En nuestro caso teníamos un checklist de 23 líneas y terminó siendo uno de 46 una vez que se volvió a importar (con el mismo nombre) al programa.
• El programa no permite descargar más de un Checklist a la misma vez (formato Excel). Por más de que estén en una carpeta aislada y bien estructurada, sólo permite ir metiendo 1 checklist a la vez (cada cargada de checklist puede variar entre (1-5 minutos)
• Los excels que se importan al BIM 360 Field sí permiten que se utilicen caracteres de otros idiomas y acentuaciones que no existen en el inglés.
• A la hora de hacer la exportación de los distintos modelos de Revit para vincularlos al BIM 360 Glue, más allá de que hay que tener los softwares actualizados al día o no permitirá hacer la vinculación, se tiene que tener ubicado la vista exacta de 3D que se quiere plasmar en el Glue. En el caso de FOC, habían al menos 10 3D’s que podíamos pasar y teníamos que estar certeros de cuál era la correcta. Tuvimos también dificultades con los vínculos de Autocad que venían adentro del modelo de Revit y no nos permitió visualizar los modelos con el Glue (por más de que no nos salía ningún error a la hora de exportar desde el Revit)
  o Anthony nos envió fotos explicando cómo lo solucionó y seguí sus instrucciones hasta poder poner los 4 modelos en el Glue y combinarlos.
  o Acordaros que no se pueden merge modelos desde Revit, se suben los modelos individuales al Glue y después es que se combinan en 1!

![Figura 4: Procedimiento para desvinvular los planos de Autocad al modelo Revit y así poder exportar el modelo al BIM 360 Glue](image)
• Revit sólo funciona al estar conectado al servidor de Sener pues las licencias funcionan al conectarse a la red de Sener e identificar que la compañía tiene las licencias vigentes. Hay que tener esto en cuenta porque los modelos tienen que estar disponibles o ya sea en el ordenador personal o a través de la conexión VPN.

• Los dibujantes tienen que hacer un mejor trabajo con el modelo, hacer un seguimiento de obra a través de Field requiere que el modelo esté íntegro y completo. De nada sirve crear familias y grupos de elementos cuando no todos los elementos (por más de que visiblemente se vean igual) contenga la misma información. La siguiente fotografía demuestra cómo el aplacado debería de ir en todas las secciones pero no es así en el modelo (no podremos darle seguimiento a estos elementos como queríamos).

Figura 5: Paneles debería de estar presentes en toda la zona, se aprecia que no es así
• Hay que definir muy bien cómo es que se quiere hacer la vinculación de los equipments a Field. Con IFC’s lo que sucede es que le asigna un valor numérico aleatorio después del nombre a cada elemento entonces imposible de agruparlos por nombre puesto que éste número hace que todos sean distintos (por más de que provengan de la misma familia en Revit). Anthony recomienda siempre crear el Equipment Set utilizando el nombre, pero me he dado cuenta que puede no ser del todo útil puesto que el nombre se escoge del Parent y los dibujantes vuelven a jugar un rol crucial en esto. Para el Aplacat Gres de Foc, si uno escoge los elementos y crea un Equipment Set utilizando el nombre del Parent, al ser un nombre semi-genérico, agarra también otros elementos que son distintos pero provienen de la misma naturaleza. Las fotos adjuntas son para demostrar esto. Por eso creo que puede ser conveniente crear equipo sets a través del Parent pero en vez del nombre, del TYPE. El type es más específico y nos ayuda a agrupar elementos que verdaderamente queremos. Lo que sucede es que de vez en cuando no nos importa tanto que sea tan específico y podríamos optar por el Name que nos daría una base más amplia.

Figura 6: Son elementos distintos que comparten nombre del Parent, así que si se agrupan por esta categoría (como recomienda el Anthony), se pueden agrupar elementos incorrectos. El Type agrega el valor añadido puesto que es más específico y algunas veces se quiere ese nivel extra de detalle.

• Cambiar el nombre de los Equipment Sets en Glue (ya sea si fue creado por Type o por Name), no afecta el funcionamiento del programa. Habrá que investigar con el Anthony por qué utilizar una versus la otra.
  o He decidido poner una T o una N después de cada Equipment Set para acordarme a la hora de hacer las vinculaciones al BIM 360 Field cual es la característica principal que queremos asociar.

• En el modelo de Arquitectura nos damos cuenta que el nivel de detalle es relativamente bajo y no nos proporciona con suficiente elementos para darles seguimiento. No tenemos ni pavimentos ni distintos muros. Definitivamente el modelo que más tiempo se le metió fue al de instalaciones puesto que el de estructural y ENV también están a un nivel bajo de detalle.
Figura 7: Modelo Arquitectónico donde se ve que no hay pavimentos y que los muros no vienen diferenciados (más allá del aplacado gres)

Figura 8: Otro ejemplo del papel que tienen los dibujantes y la calidad del trabajo que se tienen que hacer en la fase de crear el modelo 3D

- Los cambios efectuados en Glue se reflejan en Field inmediatamente siempre y cuando se esté trabajando sobre el mismo modelo (mismo nombre). He probado al cambiar unos errores de ortografía en los equipment sets de Glue y se ha cambiado al instante en el Field.
- Decido escoger como propiedades fundamentales las siguientes vistas en la Figura 9 puesto que se piensa que el seguimiento estará ligado directamente con todas éstas y era la forma apropiada de hacerle.

Figura 9: Propiedades escogidas para hacer el seguimiento de los distintos equipment sets

- Cuando se están subiendo las fichas de ejecución al Field por medio de la plantilla de Excel que nos provee el programa, hay que tratar de estandarizar estos procesos para que formular los Excels sea una tarea sencilla. En el caso de FOC L9, dado que dos personas diferentes han hecho las de instalaciones y las de arquitectura, hay discrepancias en la forma en que interpretan los espacios y la utilización de la plantilla. Lo que sucede es que entonces es más faena subir los excels pues no consiste de los mismos conceptos y hay que darle más pensamiento de lo que debería de.

- Cuando se están creando los VIEWS en el Glue, los Views vienen a establecer la situación actual del modelo. Lo que quiere decir que si hay elementos que se han escondido para poder visualizar mejor otras plantas o cualquier otra causa, no van a aparecer en el view si éste se crea bajo estas circunstancias. El View se ve igual que en el momento que se crea bajo la misma situación.

- Crear filtros adentro de los equipments (que Anthony recomienda por facilidad de la navegación) es complicado puesto que el programa es muy lento. En el caso de FOC L9 lo tenemos cargados con muchos equipments pero de todas formas el tiempo de carga es tanto que el sistema falla e impide hacer este proceso.

- Una vez subido un modelo al BIM 360 Field y linkando los equipment sets con equipment types (creados en el Field), no se pueden borrar estas categorías de types por más de que se borre el modelo y se vincule uno nuevo. El problema con esto es que si uno sube un nuevo modelo y decide utilizar otra nomenclatura, igual aparecen los nombres antiguos y simplemente estorban y confunden. Al tratar de borrarles dice que no se puede borrar porque está linkeado al modelo (cosa que es mentira ya que es el modelo viejo que ya no existe).
A la hora de estar creando las locations en los planos de PDF para vincular los issues a zonas más específicas, no permite crear locations que no sean rectangulares, sólo permite formar una zona bajo el rectángulo. Esto me afecta puesto tengo muchos cuartos colindantes que no son rectángulos y hay un solape importante entre los locations.

Durante la visita de obra efectuada el día 23/10/17, la Tablet decide cerrarme la aplicación de BIM 360 Field y éste me pide hacer el sign-in una nueva vez. En la estación de FOC no hay internet ni señal de 4g por lo que hace que se termine la cesión puesto que no puedo continuar trabajando con la Tablet sin acceder al BIM 360 Field.

Cuando se están creando pins para los issues (en el caso de sonometrías), me da la opción de add as favorite al template, pero lo único que copia es el título. Debería de
haber una opción para copy paste un pin para dar la flexibilidad de utilizarlos para algo más allá que issues en sí.
  
  - Sabemos que el tab de issues es el más útil por mucho.
  
- Cuando se toman fotografías éstas se suben automáticamente por fecha en el tab de Photos, yo he decidido hacer una carpeta de sólo fotografía puesto que uno puede tratarles como documentos y asignarle locations y tags. A la hora de asignarle locations, se encuantra que es muy incómodo ya que cuando se están poniendo PINS en 2D en el tab de los Issues, todas las fotografías asociadas a ese location aparecen como documentos y añaden confusión y basura visual. Por lo visto es mejor solo tratarlas con tags.

![Imagen de la aplicación BIM 360 Field](image.png)

Figura 12: Fotos con locations asignadas crea confusión y ensucian el trabajo

- A la hora de tomar fotografías con el iPad, éstas se graban automáticamente en el Tab de Photos. Cuando uno después adjunta una de estas fotografías a un daily update, las fotografías se duplican en el mismo Tab de Photos. Si uno después los agrega a una carpeta en Library (como nosotros estamos haciendo para tenerlas organizadas por fecha de visita de obra y también por este mismo error), se vuelvan a duplicar y quedamos con 3 copias por fotografía.
  
  - Hay que preguntarle al Anthony si hay forma de evitar esto para no cargar el sistema innecesariamente.
Figura 13: Fotos triplicadas causadas por la asignación de las fotografías a distintos usos

- Los barcodes creados para las ubicaciones, no siguen el mismo patrón que los barcodes para los equipment. Los barcodes de location sólo sirven para accesar las NC’s por la location que se ha accedido. NO SE CREA NINGÚN TIPO DE vista por la ubicación. A lo que voy es que no se pueden crear vistas a través de barcodes así por así lo cual es una lástima.
  - La alternativa es crear vistas desde el BIM 360 Glue y después actualizar la Tablet para tener estas vistas específicas (que ya se había hecho anteriormente).
- A la hora de crear vistas desde el BIM 360 Glue (una vez que ya se ha subido el modelo al BIM 360 Field) todavía no se entiende bien cómo hacer que estas vistas aparezcan en la Tablet. No estamos seguros si hay que re-vincular el modelo a Field y después re-upload todo a la Tablet (teoría Fernán), o simplemente al crearla en Glue se traspasa automáticamente en la Tablet (teoría María)
- El Library trae muy poca flexibilidad a la hora de visualizaciones, lo ideal sería poder crear carpetas con colores, cambiar los tamaños, íconos, entre otras cosas. El poder hacer estas personalizaciones ayudaría mucho a la navegación de la estructura de carpeta cuando hay muchísima información guardada.
- Los checklists que ya se han ejecutado no se puede modificar su estructura una vez que han sido abiertos y completados. En mi caso hemos tenido el problema que una de las partidas había que borrarla y por más de que se hagan los ajustes en el checklist “padre” que viene del Project admin, estos ajustes no se ven reflejados en los checklists que ya han sido completados o empezados. (caso sirenas en FOC L9).
  - Se tiene que volver a ejecutar el checklist y adherirle todas las fotografías.
ANNEX 6 Author’s Software Certificates

[Image of a certificate]

SYNCHRO SOFTWARE

CERTIFIED USER

THIS CERTIFIES THAT

Fernan Vargas

HAS SUCCESSFULLY COMPLETED THE SYNCHRO FUNDAMENTALS COURSE AND
IS RECOGNIZED BY THE SYNCHRO CERTIFICATION PROGRAM AS
Synchro Certified User for Synchro PRO 2017

March 6, 2018
Date

[Signature]
Learning and Development Manager
Synchro Software Ltd.
ANNEX 7 Summary of Implementations
Barcodes linked to specific documents within the BIM 360 Field Library for accessibility purposes.

Barcodes linked to 3D elements which contain non-conformities are positioned closely to one so that it redirects the user to the non-conformity once the barcode is scanned.

Barcodes linked to 2D issues that contain non-conformities are positioned closely to one to redirect the user to the non-conformity once the barcode is scanned.

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### Implementation - Pre-application Workflow

<table>
<thead>
<tr>
<th>Resource Status (Synchro)</th>
<th>Activity Status (Synchro)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily site visits and verifying of the elements and systems being erected on-site. The user takes his printed Gantt Chart and checks the equipment, materials, assets whose status has changed from the last visit and takes notes on it. The user takes photographs on the progression and then returns to the office to digitize the gatherings and notify on a weekly basis the rest of the interdisciplinary team.</td>
<td>Daily site visits and verifying on the activities and tasks being executed on-site versus the original project schedule and/or the three-week schedule sent by the General Contractor. The user takes his printed Gantt Chart and checks the equipment, materials, assets linked to the tasks being checked and sees whether or not the schedule is being met. The user takes photographs on the progression and then returns to the office to digitize the gatherings and notify on a weekly basis the rest of the interdisciplinary team.</td>
</tr>
<tr>
<td><strong>Digitalize the process and avoid double-entry of information as well as non-uniformity involved. No more pencil and paper and tablet instead.</strong></td>
<td><strong>Digitalize the process and avoid double-entry of information as well as the rework involved. No more pencil and paper and tablet instead.</strong></td>
</tr>
<tr>
<td>N/a</td>
<td>N/a</td>
</tr>
<tr>
<td><strong>• Interruption Set</strong></td>
<td><strong>• Planned</strong></td>
</tr>
<tr>
<td><strong>• Damaged</strong></td>
<td><strong>• Started</strong></td>
</tr>
<tr>
<td><strong>• Non-uniformity</strong></td>
<td><strong>• Finished</strong></td>
</tr>
<tr>
<td><strong>• Architectural Reception</strong></td>
<td><strong>• Photos taken while the inspection takes place</strong></td>
</tr>
<tr>
<td><strong>• Architectural Collection</strong></td>
<td><strong>• Material Specification Sheet for each of the elements</strong></td>
</tr>
<tr>
<td><strong>• Architectural Placement</strong></td>
<td><strong>• Photos taken while the inspection takes place</strong></td>
</tr>
<tr>
<td><strong>• Architectural Verification</strong></td>
<td><strong>• Photos taken while the inspection takes place</strong></td>
</tr>
<tr>
<td><strong>• MEP Reception</strong></td>
<td><strong>• Photos taken while the inspection takes place</strong></td>
</tr>
<tr>
<td><strong>• MEP Collection</strong></td>
<td><strong>• Photos taken while the inspection takes place</strong></td>
</tr>
<tr>
<td><strong>• MEP installed</strong></td>
<td><strong>• Photos taken while the inspection takes place</strong></td>
</tr>
<tr>
<td><strong>• MEP Inspected</strong></td>
<td><strong>• Photos taken while the inspection takes place</strong></td>
</tr>
<tr>
<td><strong>• MEP Testing</strong></td>
<td><strong>• Photos taken while the inspection takes place</strong></td>
</tr>
<tr>
<td><strong>• MEP Working</strong></td>
<td><strong>• Photos taken while the inspection takes place</strong></td>
</tr>
</tbody>
</table>

### Purpose

- Custom Properties (if applicable)
- Root Causes (if applicable)
- Issue Templates (if applicable)
- Report Type (if applicable)
- Barcodes Usage (if applicable)
- Use of 2D and 3D pins

### Statuses (if applicable)

- Resource Status (Synchro)
- Activity Status (Synchro)

### Benefits

- Elimination of time consumptions as processes are merged and the user can complete the inspection on-site while the data is then uploaded to the cloud service and users can access it during the inspection.
- Minimizing waste in time and resources as the firm can foresee the happening of the jobsite as the CPM will now recalculate the durations and whether the project is running on or behind schedule. The linking of the project schedule and the 3D model is also a powerful visual tool than can be shared with the interdisciplinary team.

### Methodology

The user takes the Synchro Site application to the construction site and performs the inspections of the elements on-site while collecting important data such as the status and photographs. These status changes are reflected in the 3D model in Synchro Pro which serves as a more accurate picture of the goings of the project.