EUBIM 2016

Congreso Internacional BIM / 5º Encuentro de Usuarios BIM

BIM INTERNATIONAL CONFERENCE

LIBRO DE ACTAS

www.EUBIM.com

Organizadores:

UNIVERSITAT POLITÈCNICA DE VALÈNCIA

Congreso Patrocinado por:

GENERALITAT VALENCIANA
CONSELLERIA D'EDUCACIÓ, INVESTIGACIÓ, CULTURA I ESPORT

Entidades Participantes:

GURV

ESCOLA TÈCNICA SUPERIOR ENGINYERIA D'EDIFICACIÓ

CAATIE VALENCIA
Colegio Oficial de Aparejadores, Arquitectos Técnicos e Ingenieros de Edificación de Valencia

EGA
DEPARTAMENTO DE EXPRESIÓN GRÁFICA ARQUITECTÓNICA

DEPARTAMENTO DE CONSTRUCCIONES ARQUITECTÓNICAS

forum UNESCO UNIVERSIDAD Y PATRIMONIO

UNESCO
Organización de las Naciones Unidas para la Educación, la Ciencia y la Cultura

uniTwin
Cátedra UNESCO Forum Universidad y Patrimonio

Colección Congresos UPV

Los contenidos de esta publicación han sido evaluados por el Comité Científico que en ella se relaciona y según el procedimiento que se recoge en http://www.eubim.com

www.lalibreria.upv.es / Ref.: 6338_01_01_01

ISBN: 978-84-9048-525-5 (versión impresa)

DOI: http://dx.doi.org/10.4995/EUBIM.2016.4244

COMITÉ INSTITUCIONAL

- Rector Magnífico de la Universitat Politècnica de València, D. Francisco J. Mora Mas.
- Presidente del Grupo de Usuarios Revit Valencia (GURV), D. Alberto Cerdán Castillo.
- Director de la ETS de Ingeniería de Edificación UPV, D. Francisco Javier Medina Ramón.
- Director de la ETS de Arquitectura UPV, D. Vicente Mas Llorens.
- Director del Departamento de Construcciones Arquitectónicas UPV, D. Manuel Valcuende.
- Director del Departamento de Expresión Gráfica Arquitectónica, D. Pablo Navarro Esteve.

COMITÉ CIENTÍFICO

- Francisco Ballester Muñoz (Universidad de Cantabria)
- Alberto Cerdán Castillo (Consultor BIM)
- Eloi Coloma Picó (Universitat Politècnica de Catalunya)
- Joaquín Díaz Pascual (Universidad de ciencias aplicadas de Giessen)
- Giuseppe Martino Di Giuda (Universitat Politècnica de Milán)
- Ernesto Faubel Cubells (Universitat Politècnica de València)
- Ángel José Fernández Álvarez (Universidade da Coruña)
- Begoña Fuentes Giner (Universitat Politècnica de València)
- Jaume Gimeno Serrano (Universitat Politècnica de Catalunya)
- Francisco Hidalgo Delgado (Universitat Politècnica de València)
- Óscar Liébana Carrasco (Universidad Europea de Madrid)
- Vicente Olcina Ferrándiz (Universitat Politècnica de València)
- Inmaculada Oliver Faubel (Universitat Politècnica de València)
- Miguel Rodríguez Niedenführ (Universitat Politècnica de Catalunya)
- Rafael Sánchez Grandía (Universitat Politècnica de València)
- José Antonio Vázquez Rodríguez (Universidade da Coruña)
- Augusto Mora Pueyo (Universidad de Zaragoza)
- Juan Luis Pérez Ordoñez (Universidade da Coruña)

COMITÉ ORGANIZADOR UPV-GURV

- Manuela Alarcón Moret
- Alberto Cerdán Castillo
- Amparo Ferrer Coll
- Begoña Fuentes Giner
- David Martínez Gómez
- Inmaculada Oliver Faubel
- Lorena Soria Zurdo
- José Suay Orenga
- David Torromé Belda
- Sergio Vidal Santi-Andreu

PRE-CONSTRUCTION ENVIRONMENTAL ANALYSIS WITH BIM

Di Giuda, Giuseppe Martino (1), Villa, Valentina (2)

(1) Politecnico di Milano, ABC Department giuseppe.digiuda@polimi.it.
(2) Politecnico di Milano, ABC Department. valentina.villa@Polimi.it

RESUMEN

El objetivo de esta investigación es la implementación de la ejecución de ejecución de estructuras in situ utilizando un modelo BIM para la gestión de la construcción. Cada elemento técnico del modelo se asocia a datos geométricos y técnicos, por ejemplo, las características de los materiales. La metodología BIM permite asociar documentación específica a cada parte del modelo, como por ejemplo los informes de control y las fichas técnicas. Esta es una gran ventaja para el que tenga que gestionar y utilizar esta información en el futuro durante la fase de gestión de instalaciones. En el caso de estudio que se propone asociamos a cada elemento estructural todos los informes de control: controles preliminares, controles de aceptación, controles de seguimiento y los controles finales, que son requeridos reglamentariamente para la construcción de estructuras de hormigón armado construidas in situ.

El modelo BIM se implementa con el análisis y la evaluación del ciclo de vida durante la construcción de estructuras teniendo en cuenta no solo las distintas opciones de diseño y los materiales utilizados, sino dando gran importancia a las posibles opciones de organización de obra. Esto último va a dar lugar a diferencias significativas en cuanto a los tiempos y costes en términos de impacto ambiental.

Este estudio demuestra cómo la metodología BIM permite el análisis dinámico de múltiples escenarios usando el proceso y la aplicación del modelado para la evaluación de diferentes aspectos: operativos, económicos y ambientales.

Palabras clave: *BIM, gestión de la construcción, energía, gestión de instalaciones, sostenibilidad, control estructural.*

ABSTRACT

The aim of this research is the implementation of the structural works on site using a BIM model for the construction management. Each model's technical element is associated with geometrical and technical data, for example characteristics of the materials. BIM methodology allows associating to each part of the model, specific documentation, such as control reports and technical sheets. This is a huge advantage for those who will have to manage and use this information in the future during Facility Management phase. In the case study proposed we associated to each structural element all control reports: preliminary checks, acceptance controls, follow-up controls and final controls, which are required from regulations to carry on reinforced concrete structures cast on site.

The BIM model was implemented with the analysis and the assessment of the life cycle during the structures construction not only by taking into consideration the design choices and the materials used, but giving great importance to operational choices usually made on the construction site. The latter will generate also significant times and costs differences in terms of environmental impact.

This study demonstrates how the BIM methodology allows the dynamic analysis of multiple scenarios using procedural and application modeling for the evaluation of different aspects: operational, economic and environmental.

Key words: *BIM, construction management, energy, facility management, sostenibilidad, structural controls.*

1 INTRODUCTION

The aim of this study is the implementation of the construction works using a BIM model for the information management. [1] Each technical element of the model is associated with geometric and technical data, for example, the materials' characteristics. [2] It is also possible to associate specifications to each model-object, such as control reports and technical sheets. Unquestionably, this is a great advantage for those who will manage and use this information in the future during the facility management step. [3] In the case-study presented, we associated each structural element to any control reports: preliminary checks, acceptance inspections, follow-up and final checks, which regulations require in order to implement the cast-in-place reinforced concrete structures.

A study conducted by our research group has found that the evidence gathered during the construction management, often involves a difficult control process related to traceability; often, beams and columns' identification codes are not uniform between architectural and structural design. The first part of the study was implemented with the evaluation of the environmental impact on the life cycle during concrete structure implementation. Far from being considered merely design options and materials to be used, they are very important operational procedures adopted to make those decisions and generate also substantial differences in terms of time and cost as well as of environmental impact.

By noting the lack of a process model and the evaluation implementation related to different operational methods (from an operational, economic and environmental point of view), this case study demonstrates how the BIM methodology allows the analysis of multiple scenarios in a dynamic way. [4] Furthermore, this case study let us establish a more efficient procedure: the proposed method is repeatable and can be implemented with additional analysis in order to obtain optimizations in terms of controls and checks, evaluations: times, costs and environmental sustainability.

2 METHOD

The BIM model creation and implementation method has been validated in relation to the structures involved in the extension project of an elderly-aimed building.

The intervention consisted in the construction of an extending building and the renovation of a part of a 1950s building: it was designed to include the new reception on the entrance floor and two 20 beds units with related services, gym, infirmary, assisted bathroom and a lounge/dining room for the collective activities. The kitchens, administrative offices and the laundry were already included in the existing buildings. The project provided for the inclusion of an in-line building extending on three floors which arose as a closure element between two existing parts thus creating a courtsite. One side of the new building was to be joined with the wing built in the 50s through a cast-in-place reinforced concrete structure and closures in cavity-wall masonry while the opposite side was placed on the side of a more recent building completed in 2006 featuring a r.c. structure.

The pre-existing U-shaped development built in different years and the different type of flooring in the two existing buildings, led to non coincident floor, featuring almost 2,5 cm difference between one point and another. The extending construction, about 40 m long, would have had to encircle the residential settlements thus interpolating the existing difference.

The new building consists of three floors with cast-in-place reinforced concrete structure, having a foundation plate measuring 50 cm height, r.c. ground-elevation structures, with 60x40 cm anti-seismic pillars and parting walls as well as predalles slabs-made floor.

Half of the ground floor consists of a portico entrance while the remaining part houses the reception and the first reception offices. The first and second floor have the same distribution and host the ten double rooms for guests and the common services. Part of the flat roofing is allocated to the facilities housing while the remaining part is aimed at the guests of the adjacent building and becomes an outdoor terrace. Besides new emergency lifts, a new stairs block was added to the building.

The case study has provided the modeling of the reinforced concrete structure only.

2.1 Objectives

The objectives of this work were:

1. Create a LOD 450 [5] model of the structure that includes all the resources and information needed to analyze costs, materials, necessary means and various programming scenarios of the site;
2. Add the BIM model with all ongoing controls and documents collected during the works execution thus creating, at the end, a complete and organized as-built of the site;
3. Evaluate the impact of cost, time and environmental pollution that various technological solutions involve (solid floor, predalles slabs-made floor) by using different casting modes (with pump truck or bucket) and combining both variables.

2.2 Model creation for the executive phase

To better illustrate the information systemization process through the BIM, controls and the control plan were tested on a case study regarding a new building. The latter is a cast-in-place reinforced concrete, three-levels structure consisting of 50 centimeters foundation plate, a frame of beams and reinforced concrete pillars braced by the stairs block and the elevator shaft. The floors are predalles slabs-made or solid.

The modeling process has retraced the logical design and construction process. We created two models:

- The first identifies the technical elements the building consists of (LOD 100). The technological disarticulation according to the UNI 8290, acts as a guide for the definition of any parts of the project (foundation structures, elevation structures, etc.). We have identified the geometrical characteristics of the provisional works necessary for the construction. Each technical element is then "informed", with all control sheets to be filled for the correct verification during execution.
- The second model is characterized by a more detailed definition (LOD 400). The technical element is divided into its components (formworks, reinforcement and concrete). The control sheets are then associated to each process; the control checklist and required attachments will be part of the building-related information database.

2.3 LOD 200 modeling (technical elements)

The preliminary modeling starts from the definition of the technical elements the building consists of. The reference to UNI 8290 allows the classification related to technological units and technical elements categories. The function of each structural part is identified as follows:

Foundation structure:	Direct (Foundation plate)
Ground-elevation structures:	Horizontal (beams and slabs)
	Vertical (pillars and walls)
	Inclined (stairs)

The BIM model is not a three-dimensional modeling for the definition of the volumes or structural design, but a virtual model that is used to define in a comprehensive fashion a portion of the building and to organize data and information in a simple and constructive manner. [4]

Being the control plan set according to the division by technical elements, it is essential to identify the type and the position of the same. [6]

The first model is very simple, since its purpose is to associate each technical element with all information necessary for an effective control during the construction process. This level of modeling may be attached to the contracts for the execution and contractualization of the control plan, procedures, timing, attendance and the responsibility of each actor involved in the process. At this level, in fact, BIM allows you to define a complete geometry, and consequently the acceptable tolerances for each technical element (in compliance with UNI EN 13670: 2010).

Moreover, already at this stage, it is able to connect all the control sheets introduced in the previous paragraph. By defining a control plan, integrated with the site works plan, you can immediately schedule controls in relation to the work implementation. [7]

To perform the modeling of what we have previously illustrated, we used the following parametric software:

- Revit Autodesk® 2014, a CAD and BIM program for Windows operating systems that enables the design with elements of parametric modeling and design
- Autodesk Navisworks® 2014, which is a revision package for 3D projects that allows you to open and combine 3D models and carry out simulations

Then the indications and the layout of the site reported are relevant mainly to these applications. By using Revit® for modeling it was possible to create for each type of technical element the appropriate family, complemented by the parameters needed to define it. The use of parameters allows a single family to be sufficiently flexible to address issues that might otherwise require more families to be properly handled.

2.4 LOD 400 modeling

In order to be able to perform a more detailed analysis of the technical element analyzed, with reference both to time aspects and implementation phases, we decided to transit to a higher definition level - corresponding to a LOD 400 - by controlling the project in the construction phase. For simplicity's sake we shall define this modeling step#2. Now the technical elements analyzed are classified according to the most elementary constituting processing. As regards the pillar element, we will explain the 3 main stages (distinguished by the processing stages) starting from the first deck completed:

2.5 Operational BIM model creation

The BIM model creation has not only involved the inclusion of the control plan presented but the also the modeling and the parameterization of all the elements the site consists of, i.e. machinery, provisional works, site road-system, etc. [8] All this with a view to assessing the impact of cost, time and environmental pollution involved in several technological solutions (solid floor, predalles-slabs made floor), [9] using different casting modes (with pump-truck or bucket).

2.6 Dynamic model creation with Naviswork

Software Autodesk Navisworks® provides advanced tools and powerful features that allow improving planning and operational choices, as well as project information management. It is possible to combine the multidisciplinary design objects created in the BIM model with the durations analysis developed with Project® into a single integrated project model, thus being able to run a construction simulation. By importing the time schedule from Project platform and setting the rules for establishing the connection between the graphic elements from Revit and the processing items from the Gantt chart, it is possible to generate a dynamic model. As to the individual processes definition, it is possible to identify two categories:

- The provisional works, such as the formworks, supports, scaffoldings and the security measures that are placed in the "temporary" category
- Works that involves the definitive materials laying and that are placed in the "construction" category

The BIM model allows therefore examining and simulating several site hypoteses, being able to visually and virtually analyze both the criticalities and interferences between contemporary processing, check the validity of the safety measures applied and the sustainability of the project's technological and construction choices.

The objective of this work was to set up a model that could help to evaluate the best technology from the time, economic and environmental impact point of view and the best constructive choice to build the cast-in-place reinforced concrete structures of the extending building, then defining the parameters in relation to a certain site context. The evaluation is carried out by a spreadsheet that uses as input the data related to the site analized and performances of the catalog technical data sheets of the means adopted. These data are extrapolated directly from the BIM model, are processed by the program and then output values are calculated, which will serve as a basis for the evaluation of the most suitable constructive choice. This method allows you to evaluate several operational choices and technological solutions, so that you are able to make more conscious choices more in relation to results that take into account several factors such as the site context, means and equipment, logistics, technical elements positioning, materials quantity and characteristics, supply and installation timing, controls timing, costs and environmental impact. This analysis can be considered as a reiterable method in "n" different contexts apt to propose a method which takes into account detailed dynamic analysis as real and reliable as possible, thus making the BIM project a reliable control method and a valuable support tool for the company in the formulation of the most suitable constructive choice concerning cost, time and sustainability related to the site context, which may differ every time.

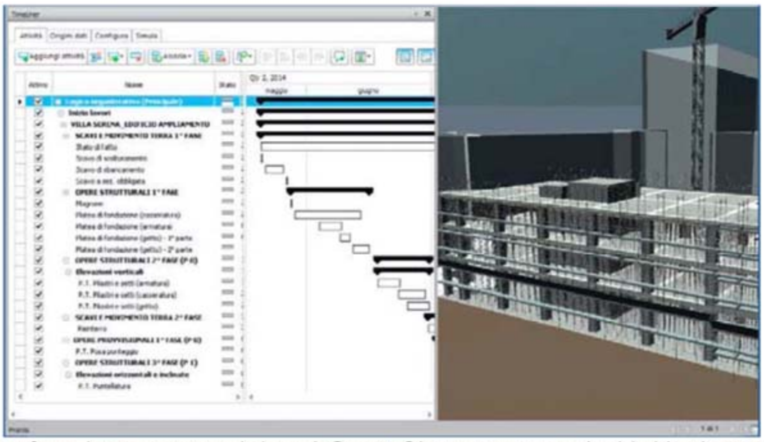

Fig 1. Interface between model and Gantt Chart generated with Naviswork program

It is crucial to emphasize that the output generated by this dynamic analysis must be information that is implemented in the BIM model.

2.7 Evaluation of technological and operational choices

Two different modes of casting structures related to the cast-in-place reinforced concrete structure will be considered, i.e.:

1) Casting with pump trucks
2) Casting with bucket

The evaluations were carried out for casting of pillars, baffles and slabs, considering for the latter two technologies:

1) Solid floors
2) Predalles-slabs made floors with composite casting

As regards the emissions assessment we have used the "CO_2 factor" defining a value equal to 2.65 kg of CO_2 per liter of diesel fuel consumed.

2.8 Dynamic analysis for the vertical structures

As to the evaluation of cost, time and emissions for the construction of vertical structures, such as pillars and partitions, two constructive modes were evaluated:

1) The first concerns the casting with bucket. This includes the use of an air forklift, for example a crane that, through an appropriate bucket, loads the concrete from the mixer truck and brings it close to the technical element to realize, releasing the concrete inside the formwork. [8] To analyze this casting mode, we need therefore to take into account:

    - The technical characteristics of the crane adopted and the handling timing (ascent, rotation, descent, translation)
    - The concrete supply method to the site
    - The redundancy of operators' constructive gestures to perform the casting and the downtime generated, which will be crucial for the scanning of the elementary and total durations
    - The duration of the vibration means and cast concrete subsidence

    From the crane datasheet we will obtain and subsequently enter essential input parameters, such as:

    - The lifting speed (during loading and unloading) in m/min, in our case: load 35 m/min – unload 50 m/min
    - The trolley travel speed (during loading and unloading) in m/min, in our case: load 0.8 m/min - unload 1 m/min
    - The arm rotation speed (during loading and unloading) in m/min, in pur case: load 25 m/min - unload 35 m/min
    - The crane travel speed (during loading and unloading) in m/min, in our case: load 35 m/min - unload 50 m/min
    - The weight of base and top ballast and the weight of the crane

    A further input element is the load diagram of the crane, reported in the technical sheet, which correlates the maximum load supported depending on the trolley travelling speed along the arm.

2) The second consists in carrying out the casting through the use of an external mechanized resource that casts the concrete (pump truck). In order to analyze this operating mode, we need to take into account:

    - The choice of the pump truck used, since it must have characteristics suitable to the site configuration and comparable to other resources it interfaces with (such as the truck mixer) [10]
    - The duration of the castings and downtime characterized by operator's gesture who must be able to reach the quota concerned for the casting of each discrete element

- The duration of the vibration means and cast concrete subsidence
- The actual consumption of the machinery subjected to different degrees of stress depending on the distance and elevation of the casting point.

Then we need to identify the exact position of the elements to implement, by setting a coordinate grid which allows calculating the distance from the positioning point of the crane and the pump truck.

Once the choice of the bucket type to use is made, we need to determine the duration of the castings. In order to assess this parameter, we will determine:

1) The number of the crane lifts needed, determined by the casting amount of each element divided by the flow rate of the chosen bucket
2) Downtimes relating to the casting release, the movements of the bucket depending on the technical characteristics of the crane, the operator's elementary gestures and the vibration operations

	VOLUMI			Distanza gru	Max. carico concesso	Capienza benna relativa	Scelta della benna	CHECK	Numero tiri di gru necessari		
	PT [m³]	P1 [m³]	P2 [m³]	[m]	[kg]	[l]	[l]		PT	P1	P2
P1	1,09	0,77	0,77	24,0	2100,00	600,00	500,00	Ok	2,2	1,5	1,5
P2	1,09	0,77	0,77	26,6	1700,00	500,00	500,00	Ok	2,2	1,5	1,5
P3	1,09	0,77	0,77	28,2	1700,00	500,00	500,00	Ok	2,2	1,5	1,5
P4	1,09	0,51	0,51	26,6	1700,00	500,00	500,00	Ok	2,2	1,0	1,0
P5	1,09	0,77	0,77	32,1	1500,00	400,00	400,00	Ok	2,7	1,9	1,9
P6	1,09	0,77	0,77	17,4	3000,00	1000,00	500,00	Ok	2,2	1,5	1,5
P7	1,09	0,77	0,77	22,6	2100,00	600,00	500,00	Ok	2,2	1,5	1,5
P8	1,09	0,77	0,77	28,9	1700,00	500,00	500,00	Ok	2,2	1,5	1,5
P9	1,09	0,77	0,77	13,3	3000,00	1000,00	500,00	Ok	2,2	1,5	1,5
P10	1,09	0,51	0,51	19,6	2440,00	800,00	500,00	Ok	2,2	1,0	1,0
P11	1,09	0,77	0,77	26,6	1700,00	500,00	500,00	Ok	2,2	1,5	1,5
P12	1,09	0,77	0,77	11,1	3000,00	1000,00	500,00	Ok	2,2	1,5	1,5
P13	1,09	0,77	0,77	25,6	2100,00	600,00	500,00	Ok	2,2	1,5	1,5
P14	1,09	0,77	0,77	11,9	3000,00	1000,00	500,00	Ok	2,2	1,5	1,5
P15	1,09	0,77	0,77	25,9	2100,00	600,00	500,00	Ok	2,2	1,5	1,5
P16	1,09	0,77	0,77	15,2	3000,00	1000,00	500,00	Ok	2,2	1,5	1,5
P17	1,09	0,77	0,77	20,9	2440,00	800,00	500,00	Ok	2,2	1,5	1,5
P18	1,09	0,77	0,77	27,6	1700,00	500,00	500,00	Ok	2,2	1,5	1,5
P19	1,09	0,77	0,77	24,5	2100,00	600,00	500,00	Ok	2,2	1,5	1,5
P20	1,09	0,77	0,77	30,4	1700,00	500,00	500,00	Ok	2,2	1,5	1,5
P21	1,09	0,77	0,77	32,2	1500,00	400,00	400,00	Ok	2,7	1,9	1,9
S0	3,47	2,45	2,45	22,6	2100,00	600,00	500,00	Ok	6,9	4,9	4,9
S1	4,22	2,98	2,98	22,9	2100,00	600,00	500,00	Ok	8,4	6,0	6,0
S2	3,47	2,45	2,45	21,0	2440,00	800,00	500,00	Ok	6,9	4,9	4,9
S3	4,22	2,98	2,98	20,7	2440,00	800,00	500,00	Ok	8,4	6,0	6,0
S4	11,26	7,94	7,94	22,5	2100,00	600,00	500,00	Ok	22,5	15,9	15,9
S5	5,79	4,08	4,08	20,3	2440,00	800,00	500,00	Ok	11,6	8,2	8,2
S6	11,67	8,23	8,23	18,3	2440,00	800,00	500,00	Ok	23,3	16,5	16,5
S7	3,26	2,29	2,29	22,4	2100,00	600,00	500,00	Ok	6,5	4,6	4,6
S8	3,13	2,21	2,21	21,0	2440,00	800,00	500,00	Ok	6,3	4,4	4,4
S9	3,26	2,29	2,29	21,9	2440,00	800,00	500,00	Ok	6,5	4,6	4,6
S10	5,45	3,84	3,84	22,1	2100,00	600,00	500,00	Ok	10,9	7,7	7,7
Totali	82,09	57,35	57,35						165	115	115

Fig 2. Number of crane lifts needed to cast the vertical structures

The use of a computational model associated with a parametric virtual reality allows defining transparent and reasoned definition of material, means and resources (human and mechanical) necessary for the execution of each individual work, also allowing the company to carry out a preventive work program as possible adhering to reality, by implementing more suitable and advantageous choices about the executive procedures to perform essential steps while optimizing timing and costs and reducing the environmental impact.

These timing depend on the work nature, the implementing measures, the quality and quantity of resources used, the site physical and environmental conditions, the teams' technical-operational skill, the organization and management of the entire implementation process. [10]

By associating the durations values to each activity and complying with the logical constructive priorities, you determine the timescale (through Gantt Chart) that allows you to monitor the work progress on the evaluation date and effectively compare what was planned to achieve and what has actually been achieved.

Once you have defined the phases contextualized in the implementation times and costs and considered the resources used, you can carry out a dynamic analysis of some operating modes for realizing the technological solutions of the structures used.

These data will be extrapolated from the BIM project and then via a simple spreadsheet you will formulate the outputs that will serve as the basis for drawing up the most suitable and reasoned constructive choice. The output generated by this dynamic analysis will return in the BIM model of the analyzed intervention, thus completing the information also in details.

In the first instance we take as example the analysis of two different ways of casting the vertical structures, i.e.:

1) **Using a crane equipped with bucket.** This mode includes the use of the site crane which, through a suitable tank (bucket) moved with the arm of the crane itself, loads from the truck mixer the concrete to bring it to the altitude and distance involved and thus allow the release of the paste inside the formwork. To analyze it we need therefore to take into account:

   - The technical characteristics of the crane adopted and the relevant handling timing
   - The concrete supply method to the site
   - The redundancy of the operators' construction gestures to perform the casting and the downtime generated, which will be crucial for the scanning of the elementary and total durations

2) **Using a pump truck.** In order to analyze this operating mode we need to take into account:

   - The choice of the pump truck used, since it must have characteristics suitable to the intervention site configuration and comparable to other resources it interfaces with (such as the truck mixer)
   - The duration of the castings and downtime characterized by operator's gesture who must be able to reach the quota concerned for the casting of each discrete element
   - The duration of the vibration means and cast concrete subsidence
   - The slump test of the concrete cast from the pump truck to analyze if the actual performance is in line with what was requested
   - The actual consumption of the machine subjected to different degrees of stress depending on the distance and elevation of the casting point .


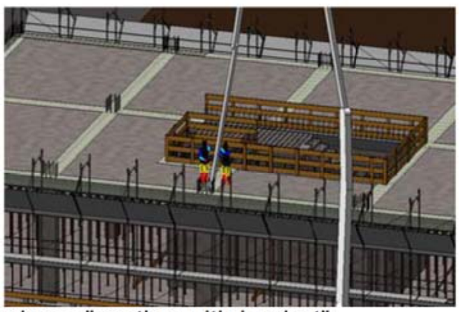

Fig 3. Modeling of the construction phase "casting with bucket"
Fig 4 Modeling of the construction phase "casting with pump truck"

By importing the data related to the vertical structures from the model in Revit, you set a coordinate system to determine the distances between the elements and means involved (pillars, crane, pump truck, truck mixer). It is important to establish for each choice analyzed the site means used to understand what is the critical resource that will determine the time. To these you will add costs and the durations of vibration and supply by a truck mixer.

For each machine used you will determine, depending on the duration of use and the relative engine performance graph, the quantity of fuel or electric absorption. Then you will estrapolate their environmental impact through the production of CO2 generated. [9]

As regards the casting with crane, which depends on the load diagram relative to the type of crane adopted, you will determine the bucket to be used and, consequently, the number of lifts required. The durations are defined by the technical characteristics of the crane (i.e. the crane lifting speed, the trolley travelling speed, the arm rotation speed and the crane travelling speed, which differs for loading and unloading) related to the site configuration and the the operators downtime to perform each handling.

To determine the execution times with the pump truck, you need to take into account, in addition to handling times relating to the technical characteristics of the means' arm and the operators' downtime, even the operational performance of the pumps: in fact, for each quota z of any x,y the power required depends on the total discharge pressure. Once you have determined the parameters of the power required for each item to cast, it is possible to obtain the value of the fuel hourly consumption to determine the associated CO2 cost and the production.

3 CONCLUSIONS

By analyzing the results obtained with the two casting methods you can see how the highest degree of mechanization in the casting implementation through pump truck affects the result, which entails a higher cost, with a total deviation of €2.930 for the total casting of all vertical structures, a time contraction of 12 hours and 23 minutes in total but even a substantially higher environmental impact with an 88% increase of the average load of harmful emissions

By setting a spreadsheet you can connect the summary sheets of the results related to the types of casting analyzed for each element, contextualized in the areas of cost, timing and emissions of CO2, with the BIM model.

By defining the position in the Cloud for sharing communication data between platforms BIM [11] and using a unique name for the sheet associated with the technical element analyzed, it is possible to connect such output sheet to the relevant element modeled in Revit via URL link. By changing the input data, the new sheet generated will overwrite the previous one, thus allowing an immediate update of the information.

To implement the dynamism degree of the analysis performed it is possible to repeat the calculation to determine the most suitable structural solution for interfloors implementation:

- Solid floor implemented through bucket
- Solid floor implemented through pump truck
- Predalles-slabs made floors implemented through composite casting with bucket

- Predalles-slabs made floors implemented through composite casting with pump truck

The calculation is bound to the critical resource used which determines the durations depending on the technical characteristics and the site configuration. The results obtained are affected by the difference in the reinforcement incidence between the solutions, thus making total costs comparable. The timing and environmental impacts will vary depending on the mechanization degree, and therefore, on the lowest percentage value of the labor force employeed.

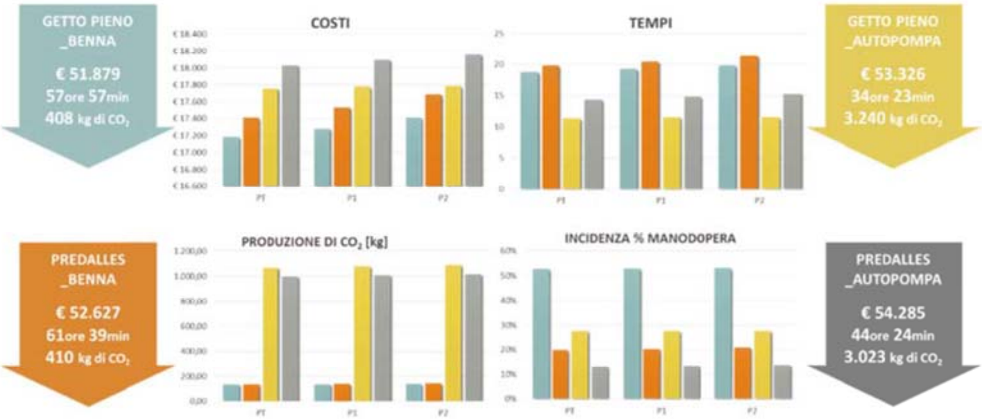

Fig 5. The diagrams of the comparison between the analyzed solutions

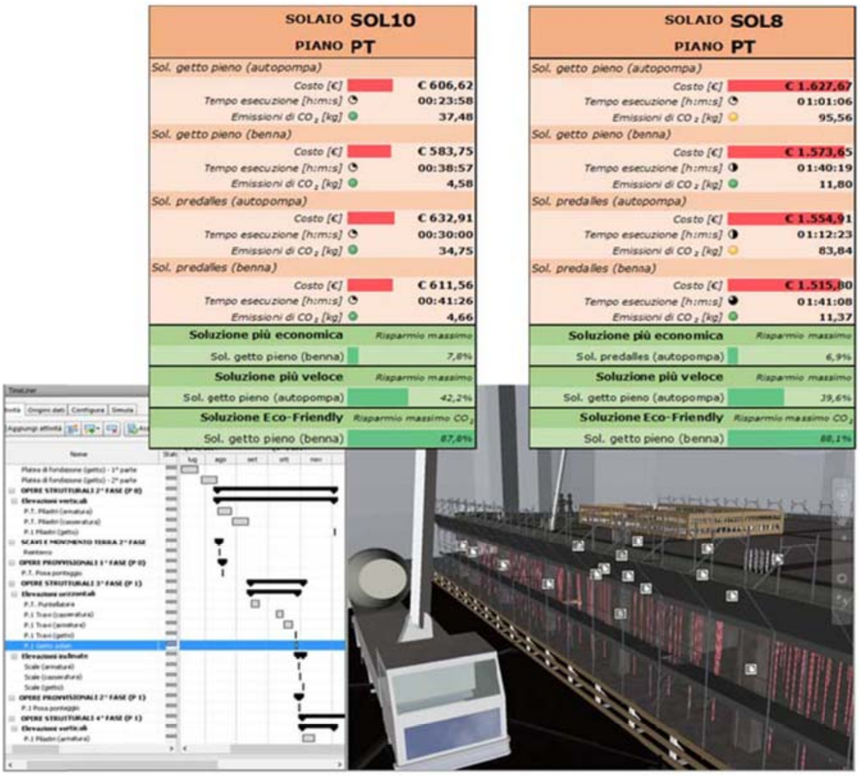

Fig 6. Display of the output for the casting of two floors

By evaluating the results histograms, it can be seen how the solid casting solution is the most advantageous in terms of time (if carried out through a pump truck), costs and environmental impact (if carried out through a bucket).

These data will be extrapolated from the BIM project and then you will formulate the outputs that will serve as the basis for drawing up the most suitable and reasoned constructive choice and implementing it in summary sheets which can be associated to the concerned element modeled in Revit. Thus, by assessing all the likely modeling options for different constructive solutions it is possible to obtain a detailed sheet and updated alternatives in order to achieve an accurate assessment of the most appropriate method to adopt. The preservation of shared parameters assigned between the platforms passage (both switching through passage in IFC and automatically from Revit® to Navisworks®) allows the consultation of the sheets assigned even on the Navisworks® platform.

Such a predictive method, based on a theoretical approach, makes it possible to carry out, in addition to a real assessment of timing and costs, an estimation of the consumption and the effective values of the CO2 emission that involves the selection of a constructive methodology over another in a dynamic analysis regime. [12] It is important to note that the results obtained in this discussion make use of the integrated design principle. By offering the possibility to manage in an integrated fashion, a complex information system, referred to the various technological systems and components that constitute the object building, this approach is essential to make sensible, functional and justified decisions by informing any actor involved in the process, from the designer to the construction company, thus allowing an immediate exchange of information and minimizing the probability of any delays and unexpected costs.

4 REFERENCES

[1] AIA. 2008. E202-2008: Building Information Modeling Protocol Exhibit. 2008.

[2] 2013. E203-2013: Building Information Modeling and Digital Data Exhibit. 2013.

[3] 2013. G201-2013: Project Digital Data Protocol Form. 2013.

[4] Il BIM: Guida Completa Al Building Information Modeling, Eastman; Teicholz; Sacks; Liston – HOEPLI

[5] New York City Department of Design and Construction, BIM Guidelines, 2012.

[6] Experiences with 3D and 4D CAD on Building Construction Projects. Gao J., Fischer M., Tollefsen T. 2005. Dresden: s.n., 2005. CIB W078 22nd Conference on Information Technology in Construction.

[7] Villa, Valentina. 2014. Controls on structures' construction, cast in place reinforced concrete structures. Politecnico di Milano: tesi di dottorato rell. F.Mola e G.M.Di Giuda, 2014.

[8] Linee_Guida. 2008. Consiglio Superiore dei LLPP - Servizio Tecnico Centrale, Linee Guida. 2008.

[9] Lavagna, Monica. 2008. Life cycle Assessment in edilizia. Milano: Hoepli, 2008.

[10] Bocchi, Giuseppe. 1987. Motore a quattro tempi. Milano: Hoepli, 1987.

[11] The NIST Definition of Cloud Computing. Peter Mell, Timothy Grance. 2011. 800-145, s.l.: NIST, Special Publication, 2011.

[12] Un futuro sostenibile ed ecocompatibile. Buscemi, Viviana. 2013. 2013, Dossier.