Successful clash management through visualization

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Background

Visual and digital information solutions have been massively invading in the last decades all domains of human activities. Visualization techniques usually contribute significantly to a comprehensive understanding of any type of processes or products.

The added value obtained by implementing these methods has also recently reached the traditionally conservative construction branch, which, in this way, has found the motivation to investigate and adopt new approaches to enhance the customary building procedures and successfully manage the entire lifecycle of projects. As a result, delays related to clashes and need for reworks are dramatically reduced and possible hindrances avoided.

The tendency in the construction market has shown in the past few years an intensive integration and application of BIM (Building Information Modelling) technology in an increasing number of projects. This growing phenomenon has been affecting not only building construction but also special foundation and infrastructure industries. BIM has introduced new digital methods for efficiently creating, processing, managing and storing project information with evident advantages and a significant reduction of efforts for adjustments and modifications in all working stages.

Among the multidimensionality of the BIM system and within the different levels of information a BIM model can consist of, the 4th dimension allows the project to be built and the construction sequence to be revised virtually before any physical action occurs at the jobsite.

Both the envision of a tangible interaction between 3D model and time schedule and the visualization of its interdependence give the possibility to simulate construction processes under different scenarios and, at the same time, the chance to analyze, control and improve all planned activities in order to attain the optimal solution in agreement with the involved parties and the reality of the site conditions.

For instance, 4D-BIM in special foundations is used to evaluate and harmonize the impact of individual processes on the overall duration of the works and, moreover, to detect unforeseen conflicts between ongoing tasks, rigs’ paths, safety issues and predefined restricted areas. In this context, site status information can be also collected, managed and visualized to obtain prompt updates and design/as-built comparisons.
This paper presents two case studies in the early and later project stage, respectively, where 4D-BIM methods were utilized for different purposes. Besides, a deeper insight into the versatility and convenience of BIM-4D solutions is provided.

Projects description: Case history 1
The first of the two projects selected for the implementation of 4D-BIM methods was a recent project in the tender phase, which involved the construction of foundation piles and an excavation pit supported by anchored retaining walls consisting of secant-pile walls and diaphragm walls. The purpose of the simulation was mainly aimed at a comprehensive investigation about the advantages that BIM-4D techniques offer for special foundation applications.

An intelligent 3D geometric model was created with the software Autodesk Revit. All 3D elements were Revit families belonging to the Züblin corporate catalog and characterized by a set of predefined parameters. Additional parameters were also embedded in the model to fulfill the specific requirements necessary for the generation of the 4D simulation with the software Bentley Synchro-PRO.

The three-dimensional model was exported as .SPX file through a Synchro-Revit plugin, while the time schedule was prepared in Asta Powerproject software. Both 3D model and time schedule were then imported into Synchro-PRO.

![Figure 1: 3D model linked to time schedule with inclusion of 3D site facilities and equipment (Project 1)](image)

The imported 3D elements were filtered based on specific parameters previously defined in Revit and arranged in resource groups to match the actual design construction sequence. Planning of the site facilities was additionally taken into consideration in the 4D simulation. 3D models of site equipment (e.g. container and silos) and rigs (e.g. drilling rigs, crawler crane and excavator) were imported and correctly scaled and moved into their corresponding position. A unique path was assigned to each machine to simulate the movements which were expected to take place during production at the jobsite.
Unexpected geometrical clashes between elements could be identified throughout the preparation of the model for the following 4D simulation. On the other hand, conflicts among preliminary defined paths and the related working spaces assigned to different machines could be recognized in the course of the 4D simulation itself by means of a dynamic clash detection.
One of the outcomes of such an investigation was an automatically generated PDF report documenting all possible collisions happening in the project. The results of the analysis are expected to support the planning team to anticipate and discuss in advance several unknown congestion issues at the site.

A proper visualization of site logistics and facilities and their mutual interaction ahead of time helped eliminate clashes, increase efficiency, and avoid last-minute changes related to unforeseen issues.

Projects description: Case history 2

The second project described in this paper refers to a project already entered in the execution stage. A 4D simulation was performed on a very complex 3D structural model associated with numerous construction phases.

The long-term goal was to develop a comprehensive conception of the interaction within all different parts involved in the building process including concrete, reinforcement, formwork, scaffolding and, at the same time, to recognize all impacts and conflicts between ongoing activities likely to appear along the timeline.

The planning of construction phases was carried out with the software Primavera-P6 and then imported with the 3D structure into Bentley Synchro-PRO.

Differently from the case mentioned above, the 3D model was provided by an external partner and delivered in a file containing no attributes assigned to the elements. It is worth noticing that despite the possibility to add new parameters to 3D objects during the preparation of the 4D simulation, this option was not considered suitable due to the high chance to receive a new revision with new element IDs.

Modifications of the geometry of the 3D elements were also mandatory and conducted directly in Synchro-PRO in order to match the actual progression of the works depicted in the time schedule.
Because of the impossibility to filter automatically the structural parts based on parameters/attributes, new filters were setup by manually selecting individual 3D objects to create resource groups. Although the procedure was extremely demanding due to the incredibly high number of elements (more than 11,000), filtering and grouping operations could be successfully accomplished.

Afterwards, the 3D elements were linked to the corresponding tasks to create the basis for the subsequent 4D analysis. However, whenever a new stage or a temporary process, which were not taken into account in the original time schedule, needed to be visualized, additional main- or sub-tasks were also introduced. Automatic rescheduling of activities was also possible to avoid conflicts between existing and newly defined items. Adjustments on the time plan operated within the Synchro-PRO file could be transferred backward to the original sources and vice versa by synchronizing with the external imported schedule.
Depending on the nature of the construction site, effective management of schedule-workspace interferences can represent a very challenging duty, which affects not only the costs and the duration of the project but also its overall safety.

Figure 7: example of 3D safety arrangement for scaffolding and construction operations (Project 2)
Safety planning was further implemented in the 4D study by specifying restricted areas and displaying safety icons during the animation in their vicinity when interferences between assignments occurred. 4D risk analysis performed at an early stage helped identify and mitigate hazards with trades working too closely or above/below each other.

Conclusions and way forward
The case histories described above present a series of applications in which 3D models of the structure were used in combination with time schedule to obtain a better understanding of the sequence of works and related technical, economical and safety risks.

Besides the solutions previously discussed, supplementary examinations for integrating the three-dimensional site layout model in the 4D simulation software were successfully conducted and, ultimately, the 3D structure, site facilities and machinery could be properly placed in the virtual environment recreated for both previous examples. This procedure enables progressive visualization of processes and highlights the mutual influence between site activities and other external boundary conditions.

To conclude, construction projects are usually complex entities characterized by many operations involving equipment and workers interacting and interfering with each other and with the surrounding context under variable regulatory conditions. Market requirements and competition have been increasing in the past years in the field of special foundations and demand a radical optimization of the construction thinking to match as close as possible the reality of the building site.

The general target of cost reduction due to unanticipated or neglected events/risks and related rework operations can nowadays be achieved through recent developments in advanced computer-assisted methods. In particular, the utilization of 4D-BIM technology has already proved in many situations to help engineers enhance the control over conflict detection or over changes occurring in the course of a project.

A more accurate planning based on 4D solutions and the consequent opportunity for stakeholders to discuss and coordinate at an initial stage all possible issues which might affect the future sequence of works helps projects to be finalized on time and within budget. 4D planning is a breakthrough in production management, and, furthermore, provides a chance to integrate safety management more intensively in the initial design phases. For instance, in special foundations, dynamic site models and visual illustration of activities (e.g. moving equipment across the whole site) represent a fundamental step in identifying risk factors.

4D dynamic models and advanced visualization tools open up entirely new opportunities to review and evaluate the traditional practice of construction management by increasing cooperation in planning, enhancing communication, and, therefore, avoiding risks before and throughout execution.