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BESTOW OF INFORMATION TECHNOLOGY IN CIVIL CONSTRUCTION

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Abstract

In Civil Construction branch of Civil Engineer to study various activities closely related to the information which is produced in any stage of the Civil Engineering business and collected, managed, circulated, and used for the efficient and effective realization of the safer and more comfortable society is known as Civil Information their tasks is Observation / measurement / production, collection/arrangement, management/circulation, usage Businesses: acquisition, Investigation, Design, Construction, maintenance, Transportation, Risk management, Weather, Environment, Lifeline. Required technology Acquisition: Clear definition of contents and its quality, estimation and choice of contents and quality of existent information Pre-processing: Format conversion and so forth Software CAD, GIS, Image processing, 3D design, planning, BIM and various business applications. When disaster strikes the land, so-called long-term reference of information can be helpful to make decision (long-term reference), Knowledge acquisition, Know-how and case-base reasoning. Management strategy suitable for lifecycle of each information should be established. Two aims of IT in Civil is discussed in this Research Paper: Information management to promote civil engineering works effectively, and to offer safer and more comfortable land space Necessity of Master-plan: Purposes, policy, organizations and their roles, rules or standards for data-exchange or data-sharing. Roles based on the master-plan: Observation, measurements, generation, collections, management, circulation, re-use or sharing, and organization to complete the purposes. Information generated on the upstream process of survey, investigation, or design goes downstream toward maintenance. In each process, additional information is generated and this information can be referred on the downstream activities.

Keywords: *Information Technology, Civil Engineering, Construction, Modeling, 3-Dimesional Deigns.*

Introduction

To set the stage for the points in this paper we first summarize current use of information technology (IT) in construction. The last twenty years have seen dramatic improvements in and widespread use of IT to describe and document the work of the many disciplines involved in construction projects. Today, practically all project information is entered into software tools or generated by computer programs and is represented in the many different formats used by the many disciplines involved in a project. The software tools tend to be general purpose tools like spreadsheet and text processing software or specialized, discipline-specific tools like mechanical CAD programs or cost estimating software. As shown in Figure 1, the formats commonly used to represent information in construction include text documents, 2D and 3D drawings, schedules in bar chart and other formats, various diagrams and charts, tables, etc. For most decisions about a project, engineers from different disciplines like those shown in the picture of a typical project meeting (Figure 1) (a designer, project manager, cost estimator, scheduler, and MEP (mechanical, electrical, and piping) coordinator) need to share their information with others on the project team. The purpose of the meeting shown in Figure 1 was to coordinate the detailed design and construction methods, cost, and schedule for an office building. In this meeting, each engineer formed an image of the current status of the project and visions of future situations in his head based on his own interpretations of the documents from the other engineers. These interpretations formed the basis for discussions and decisions about the most appropriate design of the facility and its parts, when, how, and by whom it should be built, how long the whole project or a part of the project should take, how much things will cost, etc. In this way, a large portion of the planning and coordination on the project occurred primarily in the engineers' heads and was not supported by IT. In our experience, this use of IT is typical on projects. Because decisions are mostly based on personal and human interpretations of information generated by many engineers from many disciplines the decision process and resulting actions and results are not consistent and repeatable from meeting to meeting and project to project. As a result it is difficult to predict the outcome of the current design and construction process, and IT contributes little to predict the outcome of projects more reliably. Since most of these discussions and decisions require the input of engineers from several disciplines, it is, of course of paramount importance that the information in the documents of the various specialists is based on the same information and that it is coordinated and communicated effectively. Coordinating and integrating information across disciplines and throughout several project phases has become increasingly difficult and costly as the amount of electronic information each discipline generates has increased.

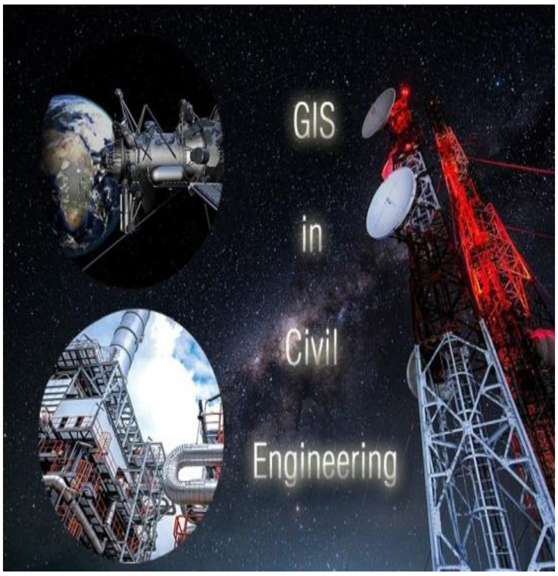

Fig. 1: On every project, several specialists from different disciplines come together to plan the project and move it forward. Each specialist documents his or her work using different IT systems and formats to represent the information they need for their work.

At the Centre for Integrated Facility Engineering at Stanford University, we have been working on methods and approaches to integrate project information and leverage information across disciplines and phases to create efficient work processes and enable better project decisions since 1988. There are certainly improvements necessary and possible in the software tools and underlying methods used by the individual disciplines today. However, in our opinion, the major opportunity for improving the design and construction of facilities lies at the interfaces between disciplines. Hence the remainder of this paper focuses on the role and scope of IT in support of multidisciplinary planning and coordination of construction projects. Finding a way to participate in such an integrated project design and construction process will be a key challenge and opportunity for individuals and firms in the foreseeable future.

2. EXAMPLES OF MULTI-DISCIPLINARY DESIGN AND COORDINATION

To illustrate the issues outlined above and to set up the role and scope of IT in construction we will consider two examples of multi-disciplinary design and coordination from recent projects.

2.1. Renovation of a large office building: A large public owner recently needed to plan the renovation of one of its largest office buildings. Several functional units of the owner (e.g., real estate, operations, human resources, project management, facility management) as well as an external design team consisting of several consultants (e.g., architect, various engineers, construction manager) considered several options for this renovation. In one approach, all the tenants in the building moved out temporarily while the building was going to be renovated. This approach gave the design team maximum flexibility and opportunity to redesign the layout, structural and mechanical systems, etc. of the building and organize its construction. In another approach, only half the tenants moved out in the first phase to make room for the renovation of half the building. After the completion of the renovation of the first half the tenants in the second half would move into the new part to make room for the renovation of the second phase, which, upon completion, would then be occupied by the tenants who had moved out originally. This approach provided significant savings in the cost of leasing temporary facilities and minimized the impact of the renovation and move on some building occupants. However, it required the careful coordination of the spaces and various building systems into two self-contained parts and the careful planning and coordination of the renovation work with the remaining tenants.

2.2. Large retail development: On a retail development that suffered a two-month delay due to unforeseen site conditions, the develop of the project asked the general contractor (GC) to develop a recovery schedule so that the project could still finish at the originally scheduled time. Together with its subcontractors the GC considered various acceleration options and analyzed their resource and other organizational needs along with their schedule and cost impact. Together with the developer and some of the subcontractors the GC also evaluated several options to redesign parts of the project to enable partial opening or faster construction.

2.3. Opportunity for IT support illustrated in the examples: These examples illustrate that many situations and decisions in construction require the involvement of several parties and tradeoff between scope, schedule, and organizational issues under consideration of cost, safety and other criteria. In the case of these projects the involved parties considered many of the tradeoffs in their heads, using some computer-generated descriptions of some of the aspects of an option, such as 2D and 3D drawings, cost estimates, schedules, or 4D models. However, virtually all decisions were made without formal predictions for the expected performance of a particular option with respect to decision criteria and business objectives.

These brief examples also highlight the challenges every company faces with respect to its physical capital assets. To provide the physical infrastructure for its own business, every company needs to:

- Understand the performance of physical assets and related organizations and processes in light of business objectives, over time.
- Predict engineering and business behaviors
- Evaluate predicted behaviors with respect to clearly articulated business objectives
- Manage the construction projects and the business to maximize measurable business objectives, e.g., Safety, Schedule, Cost, Delivered Scope, and Sustainability.
- We suggest, therefore, that the principal role and scope of IT in construction should be the support of predictions of the anticipated performance of the design of a project's scope, schedule, and organization with respect to the business objectives of the projects' main stakeholders.

3. VISION FOR THE ROLE AND SCOPE OF IT IN CONSTRUCTION

This section provides an overview of the future role and scope of IT in construction and introduces integrated POP (product, organization, process) modeling in support of the challenges noted above and defines virtual design and construction (VDC) as a design method for more effective leverage of IT in support of integrated POP design (Figure 2). The following sections review the state-of-the-art in VDC and outline a few important research issues.

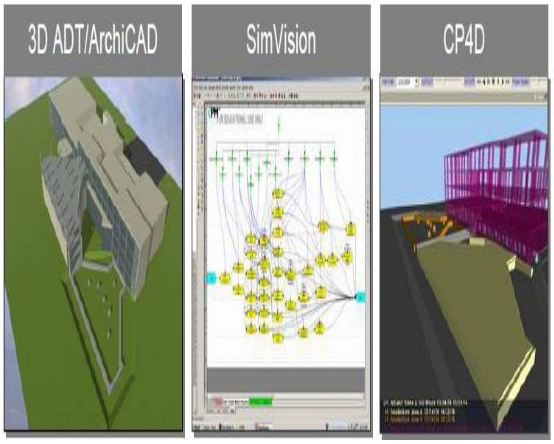

Fig. 2: Product, Organization, Process model using several commercial software tools.

3.1. Role of IT: To support such predictions, practitioners will utilize IT to simulate, analyze, and evaluate the expected performance of the facility design, the design of the facilities delivery process (design and construction schedule), and the design of the organization carrying out the process. These simulations, analyses, and evaluations should be based on an integrated model describing the designed facility, organization, and process. The simulation, analysis, and evaluation results should then be visualized so that the results make clear what the tradeoffs are between optimizing the facility, organization, and process design for a particular discipline vs. the overall project for the wide range of criteria typically found on construction projects. IT should also support automation of the generation of the input for simulation, analysis, and evaluation and automate the simulations, analyses, and evaluations as much as possible. Eventually, IT will support the optimization of a project's design from the perspective of multiple disciplines.

3.2. Scope of IT: As illustrated in the two small case examples above, the scope of IT needs to be multi-disciplinary, i.e., IT needs to support the integration of the information and perspectives about project alternatives for many disciplines. IT also needs to cover the design of the product (facility, project scope), the project organization carrying out the design and construction, and the process (schedule) to carry out the project. We call this scope ‘integrated POP design’, where POP stands for product, organization, and process. As the examples illustrate many decisions involve tradeoffs between product, organization, and process design. We suggest that the design of a project is not complete until the product, the organization, and the process have been designed and the interactions between these three areas understood. The reason for making the product, organization, and process of a project in the main scope of IT is that project stakeholders can decide what to build, who should build it how, and when to build it, i.e., the product, organization, and process design are the independent variables on a project. These decisions then lead to a particular performance of the integrated POP design with respect to cost, safety, and other project criteria. These performance predictions provide the yardstick to evaluate the relative and absolute merits of a particular design. Such an integrated POP design requires the modeling of the systems and components that make up the product, the actors, teams, task assignments, and other organizational aspects, and the activities that comprise the design, construction, and operations processes. The activities provide the main glue between the product design and the organization, since each component of the product design leads to one or several activities for its design, construction, and operation, and each actor or team in the project organization is assigned to one or several tasks.

Definition of Virtual Design and Construction: Today, integrated POP design is largely done in the heads of project participants. We envision that integrated POP design will be carried out increasingly with IT. Modeling, simulating, analyzing, visualizing, and evaluating the performance of the product, organization, and process with IT simulates how the real project might happen. Therefore, we define Virtual Design and Construction The advantage of computer-based POP design is that POP design is carried out with formal (computer-interpretable) models of the product, process, and organization. This is important to make the models and corresponding predictions and decisions consistent on a project and from project to project. Such a consistent design process will make it more likely that explicit and public project objectives can be addressed in an objective way. In summary, VDC provides an integrating theoretical framework to predict engineering behaviors, and systematically manage projects and the business using the predictions and observed data, to achieve measurable business objectives. The theoretical basis for VDC includes: Engineering modeling methods for the product, organization, process

- Model-based analysis methods including, schedule, cost, 4D models, process risks, etc.
- Visualization methods
- Business metrics, strategic management
- Economic impact (i.e., models of the cost and value of capital investments)

We are not aware of a project that has been designed, planned, and managed with integrated product, organization, process models that relate the different levels of detail needed by the key project stakeholders across disciplines and project phases. However, aspects of POP modeling can be found on many projects.

The most relevant technologies are 3D, 4D, and building information modeling and organization-process modeling and simulation. The following sections review the role and scope and application of these technologies as observed in practice today.

4. PRODUCT AND PROCESS MODELING

3D models are the prevalent method to represent the information that relates to the physical scope of a project. They are used increasingly on many types of projects, and their visualization and data modeling functionality and interfaces are increasing rapidly. Since 3D modeling technology is well-known, we will not elaborate it in this paper, but rather focus on 4D modeling, since 4D models integrate the spatial and temporal aspects of a project.

4.1. The 4D Concept: 4D Models link components in 3D CAD models with activities from the design, procurement, and construction schedules. The resulting 4D model of a project allows project stakeholders to view the planned construction of a facility over time on a computer screen and to review the planned or actual status of a project in the context of a 3D CAD model for any day, week, or month of the project.

4.2. 4D Model Benefits: 4D models enable a diverse team of project participants to understand and comment on the project scope and corresponding schedules in a proactive and timely manner. They enable the exploration and improvement of the project executing strategy, facilitate improvements in constructability with corresponding gains in on-site productivity, and make possible the rapid identification and resolution of time-space conflicts. 4D CAD models have proven particularly helpful in projects that involve many stakeholders, in projects undergoing renovation during operation, and in projects with tight, urban site conditions. For example, Walt Disney Imagineering used 4D models to plan the construction of the Paradise Pier portion of Disney's recently opened California Adventure in Anaheim, CA. Tight site conditions, a must-meet completion deadline, and many non-construction stakeholders made the project ideal for the application of 4D project management. The 4D model enabled the project team to produce a better set of specifications and design drawings for the construction of the project, resulting in fewer unplanned change orders, a smaller construction team, and a comfortable completion of the project ahead of schedule. Figure 3 shows several snapshots from the 4D model built for this project.

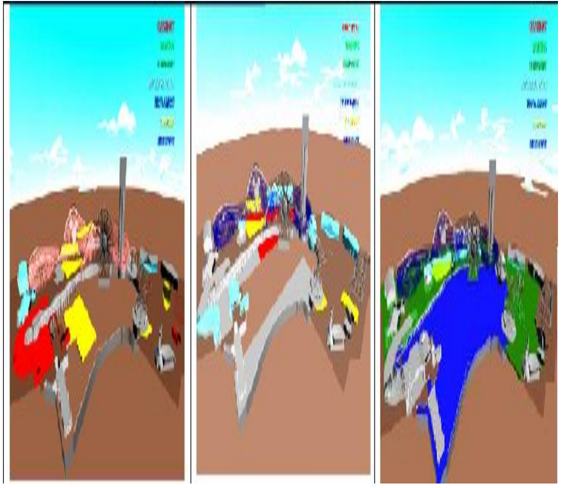

Fig. 3: 4D model snapshots

By improving project communications, the 4D models have reduced unplanned change orders by 40% to 90%, reduced rework, increased productivity, and improved the credibility of the schedule and the project management teams. The application of 4D modeling also demonstrated that an easy to learn and use 4D interface that allows the project team to maintain an up-to-date 4D model with little effort and that makes it possible to explore schedule alternatives easily is essential for the widespread deployment of 4D models.

4.3. The Project Manager's Desktop: 4D Interface: An interactive, easy-to-learn and use, and flexible 4D modeling software was developed in collaboration between Walt Disney Imagineering Research and Development and the Center for Integrated Facility Engineering at Stanford University shows the interface to the 4D software, which runs on the Windows platform. This interface allows the 4D modeler (typically the project scheduler) to organize, link, and view all scope and schedule information necessary for 4D modeling. The hierarchical organization of the project information makes it easy for the user to maintain the 4D model over the life of a project as more 3D and schedule detail become available. The drag and drop functionality makes it easy to link 3D model components and activities. The resulting 4D model enables everyone interested in a project to grasp and review schedules quickly.

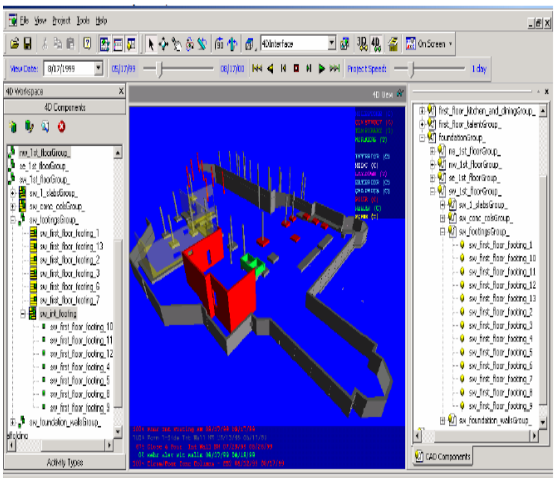

Fig. 4: 4D Model Interface

The top part of the interface contains the time and space controls to orient and position the 3D model in the central window and to move through time in various ways (selecting a date, moving the time slider, or using the video-like controls). Users can also select the speed (intervals) for displaying the model. Here, the speed is set to 1 day, meaning that the 4D View window will show the activities that will take place on the various 3D components day by day. The CAD Components window shows the hierarchical organization of the 3D components that make up the building. This 3D model organization is imported from a Virtual Reality Mark-up Language (VRML) file produced by any 3D modeling software. The Schedule window shows the activities that are needed to build the project. The colored boxes next to the activity names indicate the color in which a particular type of activity will be displayed in the 4D View window. The activities and corresponding fields are imported from scheduling software like Microsoft Project or Primavera's Project Planner. The 4D Components window shows the 4D components organized hierarchically. A 4D component includes one or several CAD components (copied from the CAD components window) that is linked to one or several activities from the schedule. The 3D model can be reorganized in any way necessary for schedule visualization. For example, the 4D modeler grouped several of the footings from the CAD Components window into a 4D component (highlighted in the 4D Components window) highlighted (rebar, form, pour). The 4D View window shows the pouring of the concrete for these footings on Aug. 17, 1999 in red as well as other activities scheduled for that day in their respective colors.

4.4. Implementation of 4D modeling: On every project, project managers, superintendents, and schedulers run mental 4D movies in their heads to think about the construction of the project. These professionals find it easy to relate to 4D models and to understand and use them. The application of 4D models has been particularly successful when focused questions about the constructability of a design and related schedule are asked (e.g., in what sequence should the roller coaster for the Disney project be built). Owners and contractors have been able to build 3D and 4D models that help address such questions within a few dozens of hours, which makes it economical and beneficial to support a project team's decision making with 4D models

The facility has started or in the early phases of project design for purposes like the following:

- 4D models for multi-year, multi-phase campus retrofit/renovation projects to sequence the individual building projects in the best possible way to support operation of the campus during the retrofit phase
- 4D models for reconstruction of facilities while they are under operation to collect the input of the affected stakeholders and synchronize construction with the operation of the facility

- 4D models for the construction phase of projects with tough temporal or spatial conditions to provide early constructability input to the design
- 4D models for the expected (predicted) degradation of a number of buildings over their life cycle to match the needs for a level of service from a facility to the business drivers and objectives related to the facility owner's core business

During detailed design or early construction phases, 4D models have been used in the following ways:

- 4D models to plan construction work in detail to coordinate the various subcontractors and make them more productive.
- 4D models to simulate the operational procedures to refine the procedures and to keep up the operational input to design

4D models built during the start-up and operational phases have focused on issues like:

- 4D models of the operational procedures to train operators and make the start-up phase more productive
- 4D models of the life of facilities to plan future extensions, maintenance activities and budget in relation to the business needs of the facility owner

5. EXAMPLES OF 4D MODEL APPLICATIONS

5.1. Helping an owner visualize the future: DPR Construction has used 4D models to win two major expansions and one new hospital construction project. A 4D model links a project’s 3D model to the schedule and generates a 3D model for any desired time interval (e.g., for each day or week of the project). A 4D model can be viewed as a continuous movie of the steps to get a project done or in snapshots at selected time intervals. 4D models allow the rapid study of different design and schedule alternatives. DPR’s project managers used 4D models to demonstrate to hospital administrators that they had the best approach for maintaining 24/7 operation of critical care facilities. In all three projects DPR won, hospital administrators approved a budget line item for 4D modeling after seeing the 4D model during the proposal stage. Administrators have subsequently used their 4D models to educate physicians and staff about what would be happening during each stage of construction. DPR’s 4D models subsequently maximized the construction staff’s understanding of the operational needs of the hospital so that the construction approach and schedule minimized the risks to the hospital operations. On one hospital campus, the 4D model alerted the hospital to the need to change the flight plan for the medieval helicopter during steel erection (Figure 5).

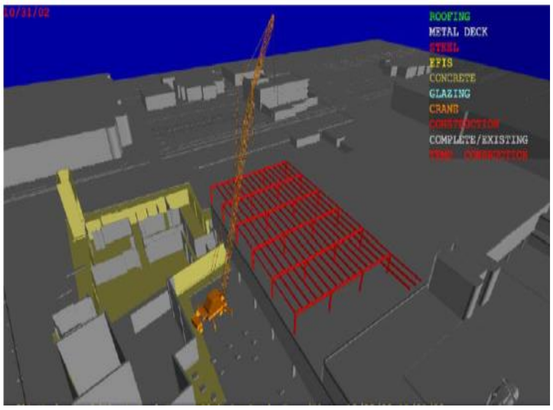

Fig. 5: Early identification of the interference in 4-D

6. 3D MODEL – COST INTEGRATION

Designers and contractors are starting to take advantage of automated quantity takeoff functionality available in 3D CAD tools for cost estimating. 3D CAD tools have offered the ability to take off quantities for quite some time, and estimating tools, such as Timberline’s Precision Estimating, have been able to import these quantities as part of an estimate’s quantity takeoff (Figure 6). Cost data that is represented to match 3D design data will enable engineers to leverage design data for cost estimating much more rapidly than possible today. For example, Webcor Builders in San Mateo, CA, experimented with the use of 3D models for automated quantity takeoff and found that estimators could build a 3D model (with Autodesk's Revit software) and take off a project's quantities in less than half the time than they would need for the same quantity takeoff from 2D drawings **(Bedrick 2003).** In addition to the advantage of doing the same job faster, such a model-based quantity takeoff reduces the variability of takeoff numbers between different estimators and greatly increases the speed of re-estimating a project when the design changes.

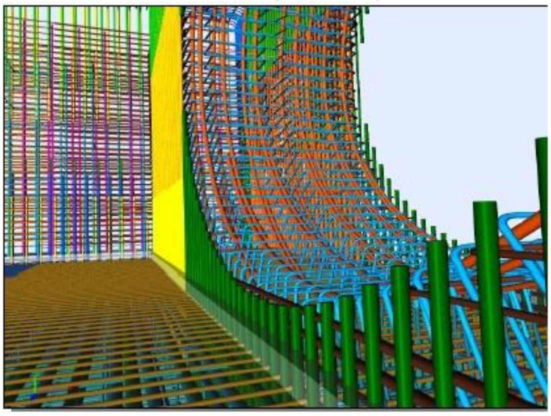

Fig.6: Detailed, integrated reinforcement steel design with 3D models

7. ORGANIZATION-PROCESS MODELING AND SIMULATION

The goal of the Virtual Design Team (VDT) project was to develop theory and tools that enable project managers to build computer models, or "virtual prototypes," of their project work processes and organizations, and then use the computer models to predict the performance of the project organization executing the given tasks. The VDT research project team had the vision that we could build theory and tools that enable project managers to design their organizations in the same way as engineers design bridges. With a theoretically founded organization and process analysis tool, a project manager could systematically diagnose schedule, cost, and quality risks associated with the planned configuration of the project. The PM could then "flight simulate" the project to explore the impact on project performance of a series of managerial interventions aimed at eliminating or mitigating these risks. After more than a decade of research and application, we, our students and collaborators have now used the VDT method

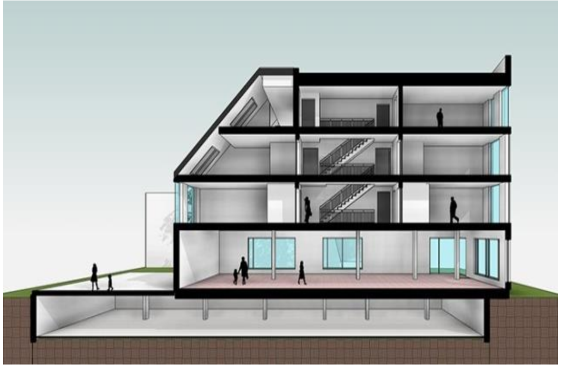

Fig 7 : 3D computer model

8. BARRIERS TO EFFECTIVE USE OF VDC

In this section we would like to briefly explore some of the barriers we have observed towards effective adoption and use of VDC. It is important to be cognizant of these barriers because they often thwart implementation efforts, but they also present opportunities for companies who find a way around these barriers and for researchers to develop more integrated and automated approaches to POP design.

In our experience these are some of the significant barriers today:

- Owners (CFOs) assess costs, not value of projects: We lack a formal and accepted method to determine
- the value of projects.
- AEC industry culture and methods minimize cost, not maximize value: Many IT systems are in place to
- account for costs, but very few examples exist of IT systems that address the value of projects. The same
- is true for university courses in construction.
- Sharp theoretical basis: Much of POP modeling and the interactions between product, organization, and
- process at the various levels of detail, across disciplines and project phases still needs to be formalized.
- Use that leads to improvement in the process and theory: We lack well-established metrics that would

- allow us to articulate the improvements VDC methods make over existing processes.
- Integrated tools: As noted the integration between the current commercial and research tools used for
- POP modeling is still challenging and time-consuming.

9. CONCLUSIONS

The many examples above show that many companies involved in the planning, design, construction, and operation of facilities are already leveraging their human assets and their information and information technology assets through the use of virtual building models. Companies use three different types of virtual building models (or POP – product, organization, process – models):

• **Visual 3D and 4D models:** These models help involve more stakeholders than is possible today early in a project to inject their business and engineering knowledge into the design of the facility, its schedule and organization, and they help to improve coordination in all life cycle phases. Such models can be built quite quickly today with commercially available software and can typically be funded from project budgets. They also currently offer an advantage to companies in getting work, but I don’t think that this advantage will be sustainable in the long run. In the long term companies will need to figure out how to deploy such visual models effectively and efficiently across their projects.

• **Building Information Models:** These types of models support the exchange of data between software tools to speed up analysis cycle times and reduce data input and transfer errors. Their set-up, testing, and use cannot typically be financed on a project basis, but rather requires corporate funding. For example one innovative engineering company has been employing about 10% of its engineering staff in its R&D group to make their software and design methods based on product models and to learn how to use product model information other project participant’s produce to their benefit. When successfully deployed, the ability to reuse project data to do more work with the same budget or the same work with far less budget should provide a competitive advantage that is more sustainable than that gained from visual models.

• **Knowledge-based models that support automation:** These models formalize and apply business and engineering knowledge to automate many of the tasks that are today repeated on a project and from project to project. Hence an organization’s capacity to process information becomes the limiting factor in determining schedule, cost and quality performance. Therefore, IT needs to support an organization’s capacity to model, analyze, simulate, and predict a project’s performance as outlined in this paper.

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