ENERGY, PROCESS & UTILITIES

OPTIMIZED PLANT CONSTRUCTION

Deliver projects on time and on budget

The Optimized Plant Construction Industry Solution Experience, powered by Dassault Systèmes **3D**EXPERIENCE® platform, provides construction excellence for large and complex systems and helps us answer this very significant question: if we can validate, describe, and trace the construction of a plant using its virtual clone, can we deliver on time and on budget?

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EXECUTIVE SUMMARY

Energy is the lifeblood that has accelerated the development of modern civilization. However, after a 20th century characterized by an abundance of energy for a limited number of countries, today all the peoples of the earth are demanding the same level of comfort. This increasing demand calls on governments to develop new energy production facilities while at the same time requiring them to upgrade those that already exist. Environmental and safety concerns increase the overhead costs of these already capital-intensive projects. For example, renewable energy, which is already more expensive per kilowatt hour (kWh), requires, because of its intermittency, a complementary equivalent capacity in backup or new long-distance grids to take advantage of shifts in currents, depending on where the wind blows. In a period of repeated financial crises, the inability to properly manage projects and control construction costs, delivery, and start-up times hinders a company's ability to generate revenue and, as a result, does serious damage to giant companies and pushes smaller ones to bankruptcy.

Capital project execution still suffers from low worker productivity where much of the day is spent waiting or planning. But construction work, in itself, is not efficient enough because it is affected by rework and lack of worker training or preparation. This is mostly due to improper or ambiguous design specifications and the late realization that construction is not possible. Today, more than ever, collaboration is required between stakeholders because supply chains are more global and equipment is more complex. The Optimized Plant Construction **3D**EXPERIENCE is designed to transform collaboration into something natural so that all stakeholders derive immediate benefits with respect to productivity, visibility, and the certainty that they are working on the latest most accurate information. Project teams can seamlessly create, collaborate, share, and manage information globally using best-in-class templates with predefined phases, gates, and milestones. Project managers can focus on high value-added activities, while dynamic dashboards obtained in real time provide scorecards, thereby eliminating tedious tasks and processes.

The strength of the Optimized Plant Construction **3D**EXPERIENCE lies in its ability to consistently handle the relationship between all aspects of a document's lifecycle. The system links engineering document delivery tasks, the digital format of the engineering documents themselves, and the validation workflow for each delivered document. All stakeholders access the same single source of information, enabling visibility for key project stakeholders, with access rights depending on a person's role and organization. More generally, for capital project execution, the Optimized Plant Construction **3D**EXPERIENCE provides project lifecycle management (PLM) during all phases from planning to engineering, procurement, construction, and commissioning, with relevant and adapted features for each specific activity. Consistency is ensured with generic project management features that can be used by all macro-processes, such as planning or tasks. The system can also couple information belonging to different macro-processes for project optimization. This execution backbone enables better decision making because it presents the right information in the right form at the right time.

While fully supporting 2D drawings, customary in plant construction, the Optimized Plant Construction **3D**EXPERIENCE also helps reduce ambiguity of design information with 3D-based tools that enable construction simulation and training. Simulation provides an effective way for engineers to develop precise and detailed plans to execute work "right the first time." 3D interactive instructions of virtually validated work operations can be digitally transferred to the crews. It also minimizes the need for textual explanations and is an efficient way to teach workers how to do the task in the most efficient and safe manner. These are typical construction operations that are usually described in corporate manuals in text format.

The Optimized Plant Construction **3D**EXPERIENCE improves collaboration based on a single source of truth and unambiguous information giving real-time project status visibility to all project stakeholders according to their needs. It delivers an execution and decision integrated environment enabling the construction of the plant with minimum waste with respect to time, cost, and resources.

INDUSTRY TRENDS

Energy is the cornerstone of economic prosperity. With a stable, affordable energy supply, industrialized nations thrive, and emerging nations embrace new opportunities.

Today the world is at an "energy crossroads." Energy consumption is growing rapidly and massive investments are required for many reasons:

- Oil is not yet replaceable on a large scale for transportation. It remains the most practicable and efficient energy source to fuel the expected doubling of the number of vehicles on the road. However, oil resources are dwindling with no massive investments on the horizon for extracting more difficult to reach crude oil (for example, deep waters, arctic sea ice, and oil sands).
- In the nuclear sector, fusion remains a scientific challenge and fission is still the only solution. The number of Nuclear Power Plants (NPPs) will grow significantly, but the Fukushima accident and the public's subsequent refusal in many countries to pursue the nuclear option cast doubts on the massive renaissance of this industry forecasted at the beginning of the 21st century. Drastic safety measures will have to be guaranteed if any acceptance from the public and governments is to be obtained.
- Despite higher investment costs for each kilowatt (kW) produced, renewable wind and solar power are progressing rapidly, reaching a two-digit percentage of the power balance in some countries. But now that they have become significant, it appears that they require a significant backup of almost 70 percent of their capacity by other resources to cover their intermittency. This backup must be able to start up and shut down rapidly, a requirement that mostly hydro power and gas turbines can fulfill. Another solution is to balance statistical intermittency between distant wind fields, requiring an overhead of new long distance transmission grids.
- Fortunately, there are many potential hydro sites remaining, but pumped-storage overhead capability is becoming an increasingly required feature.
- The use of coal is currently growing globally and is still a serious long-term option. But because of global warming, to remain an acceptable energy option on a large scale, coal would require overhead investments in Carbon Capture and Storage (CCS).
- The 21st century is already being labeled "the golden age of gas" thanks to unconventional gas discoveries and their rapid development into production.

Energy companies are facing the double dilemma of having to meet consumption demands at a reasonable price to avoid population revolts and the need to make a profit. And this at a time when demand is growing and aging plant facilities require important capital investments to upgrade or even to build new ones. All types of plants now have overhead costs generated by having to increase the safety of nuclear plants, developing backup capacity or grid extension for renewable intermittency, investing in CCS for coal-fired power plants, extracting oil from more difficult fields, and requiring pumped-storage equipment in hydro plants.

INDUSTRY CHALLENGES

Very often during the execution of complex and large plant construction projects, costs and schedules do not always go according to plan. According to a Booz Allen Hamilton survey of energy leaders, capital projects in oil and gas frequently exceed both schedule and budget by more than 10 percent (Figure 1), especially in the case of megaprojects. In such multi-billion dollar programs, a schedule overrun of even one single percent has a serious negative financial impact. The pitfalls the survey highlighted included performance management, risk management, and project planning.[1]

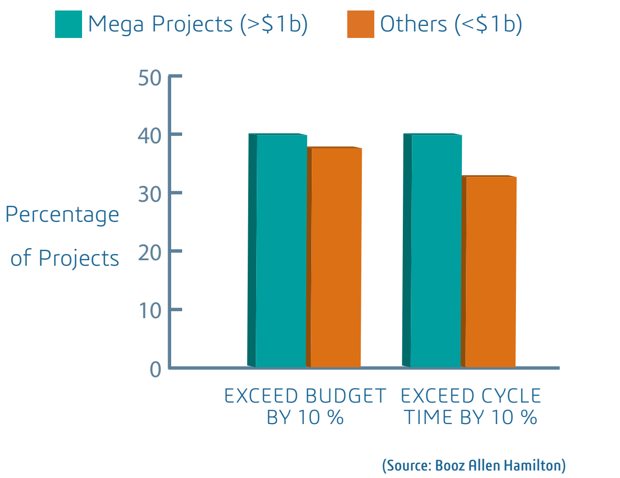


Figure 1. Percentage of projects exceeding budget and cycle time by more than 10 percent

However, a 10% overrun is even considered good performance in an industry where some projects can reach a 100% cost overrun! This is illustrated in some recent well-known stories in the nuclear power industry, or in oil sand field facilities.

There are many reasons for cost overrun, which we can separate into two main categories:

1. **Productivity rate** in large construction projects is low. A 2006 study from The Construction Owners Association of Alberta, the Albertan Government, and McTague and Jergeas has identified that crews spent actually only 33% of their time building on Alberta Mega Oil Sands Projects. They spent the remaining time planning how to do the work and waiting for materials and equipment (Figure 2). They estimated that a 25% reduction in labor costs could be achieved simply by recovering these productivity losses.

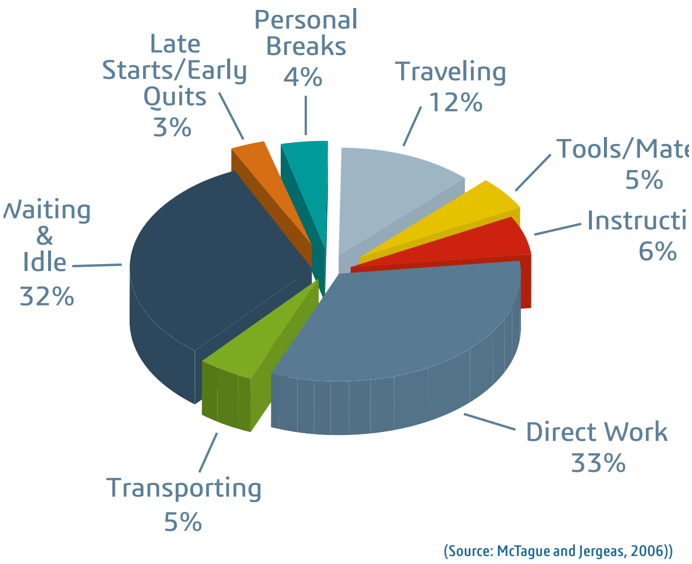


Figure 2. Time segments of a typical construction day

2. **Nonoptimized work** during actual construction is an unfortunate additional drawback. Work that is not optimized can be due to workers who are not completely trained. This requires them to spend too much time doing the work or having to redo it more than once. Improper planning can lead workers to perform an operation that originally appears feasible, but that turns out to be impossible to complete. This can involve moving equipment before doing an assembly and realizing too late that there are materials obstructing the way, interferences, or missing prerequisites. Design inconsistencies and errors also cause extra work. One example involves passing pipes in a concrete wall that was not specified as requiring holes. This leads to performing additional work to punch holes with a jackhammer.

Problems associated with the engineering design and engineering planning of a plant's construction are mainly:

- **Incomplete design quality:** Even though plant facilities are now typically designed in 3D, the construction plans are supplied by engineering with a large number of 2D drawings and specifications. Drawings are difficult to read and ambiguous because they are 2D views and some do not even depict perspective views. But they are also incomplete because the original 3D design used to generate them is also incomplete. This is often because many details are left as implicit (for example, not showing every screw and bolt as required in airplane design). Considered standard practice in the construction industry, these details are not explicitly defined. They are, however, sometimes described in industry standard documents that range from safety regulatory instructions for critical safety components to company or country standards. A customer company may, for example, define its own way of making concrete walls that contractors have to respect.
- **Error in design:** There are still errors in design, especially when integrating information from all the disciplines such as the previous example involving missing holes in the wall. This leads to extra delays and costs of having to perform tasks that were never originally planned. Even though design is mostly done in 3D, the various design disciplines such as building/civil design and piping design are not always done using the same design solution. Or if they are integrated, it may happen that the generated 2D drawings given to contractors are not the latest version that includes where the holes were added. These issues are often solved directly on the field by creating an opening or deviating pipes to a nearby opening. These issues not only affect the construction phase but may also impact other downstream operations. Simply making these corrections without going back and iterating with engineering can have an impact on satisfaction of plant requirements (structure resilience/fluid circuit). Moreover, corrections made in the field are seldom reported in the design, which results in providing the wrong engineering package to the plant operator after commissioning.
- **Lack of constructability:** As with the implicit details in a design, the way to perform assembly operations is often left up to the contractor. Traditional project management does not pay attention to a detailed planning of operations, which has always been left up to the contractor to decide. In complex facility constructions, several assembly operations are sensitive. They can only be done in a given sequence, are dependent on prerequisite tasks from other contractors, and require the construction of some specific tooling. The consequence is often that assembly is not right the first time; it needs several trials, which invariably increase delays. Sometimes it is not even possible because prerequisites are missing, which requires having to wait for tooling to be created, thus generating non-productive time for workers. An attempt gone awry can even damage equipment resulting in additional equipment replacement costs.

In a global fragile economic context with debt creating an ongoing and significant financial crisis, the development of new installations for resource production and power generation can no longer afford the 20th century comfort of long projects with delays, cost overruns, and low worker productivity.

The Optimized Plant Construction **3D**EXPERIENCE is designed to enable capital project execution excellence. This will help energy companies improve capital expenditures, accelerate time to first fuel or startup, and increase return on investment (ROI).

COLLABORATION-BASED PROJECT LIFECYCLE MANAGEMENT

Delivering projects on time and on budget is increasingly complex for owner-operators (O-Os) and engineering, procurement, and construction companies (EPCs).

Project managers already have a more global supply chain with several tiers of suppliers. Managing the complete supply chain is increasingly mandatory to respect regulations, in particular for characteristics such as delivery quality, sustainability, and safety. Cases also exist for which project governance is shared between several partners grouped in a consortium for the purpose of sharing investments to mitigate project risks.

One of the most significant challenges to "building new or refurbishing old" is the ability to manage and synchronize project information that is undergoing constant change and revision. Enforced collaboration between all stakeholders is, therefore, mandatory to keep a project on track where each player may pull in opposite directions resulting in the need to manage deviation consequences afterwards.

The Optimized Plant Construction **3D**EXPERIENCE helps transform collaboration into something natural, providing all stakeholders with immediate benefits in terms of productivity, visibility, and the certainty that they are working on the latest most accurate information. The Optimized Plant Construction **3D**EXPERIENCE manages all aspects of a project in one single system, facilitating enterprise-wide collaboration and improving project ecosystem productivity through "single source of truth" information, and managing project information by means of routes, workflow, lifecycle, and versioning.

Project managers can focus on high-value activities, while dynamic dashboards obtained in real time provide scorecards that eliminate tedious tasks and processes. Project teams can seamlessly create, collaborate, share, and manage information globally using best-in-class templates with predefined phases, gates, and milestones. Assets of reusable knowledge are continuously being created out of normal project interactions enabling new projects or future project phases to be jump-started.

The Optimized Plant Construction **3D**EXPERIENCE provides PLM during all phases from planning, engineering, procurement, construction, and commissioning, with relevant and adapted features for each specific activity (see Figure 3). It ensures consistency with generic project management features that can be used across all construction macro-processes, and by coupling the macro-processes to globally optimize the project.

Figure 3. Main gates of engineering work package deliveries

ENGINEERING WORK PACKAGE

Very often during execution of complex and large plant construction projects, design defects or ambiguities are identified too late. It is the downstream macro-processes after engineering—construction, procurement, and commissioning—that later experience major problems because delays multiply when a delay in one macro-process affects another downstream macro process.

In the engineering process for capital projects, design is done in two complementary ways: process engineering is represented by 2D diagrams with specific rule formalisms, such as Process & Instrumentation Diagrams (P&IDs) or Instrumentation and Control Diagrams (I&Cs). Later in the design process, the plant is depicted in 3D, with equipment, pipes, and civil works represented with their actual dimensions. Historically, the physical design was done on paper in 2D represented by several views with standard formalisms. Currently, this is mostly done in 3D with digital tools. Nevertheless, a digital 3D design is difficult to validate and difficult to deliver to contractors working out in the field at the plant facility. Therefore, the common practice is for engineering to deliver a list of contractual 2D physical drawings. In practice, there are automated capabilities in the 3D design software to generate the various 2D physical views from the 3D digital "best so far" design. These 2D drawings are usually frozen in PDF documents and are easily printable. These documents are the ones that are validated by all stakeholders who must review the project. In general, this is engineering management, project management, and the customer representative, and also downstream users, such as procurement or construction engineers, and certification organizations.

In fact, drawings are not the only engineering deliverables. Engineering deliverables also include specification documents, Bills of Equipment, and Bills of Materials (BOM), for example. Currently, these deliveries are often still signed on paper and then the signed paper is scanned and stored in PDF format. Engineering deliverables are grouped/dispatched in work packages depending on downstream needs, often attributed as contractor lots during a quotation submission process.

During project planning, there is a delivery timetable for all these documents. Delivery dates have been defined at project start according to downstream requirements. In this way, civil engineering documents will be ready before detailed electric cabling. The engineering deliverables are completed over a very long period of time, and downstream processes such as procurement and construction also start long before the end of engineering. Mastering this long delivery plan is difficult because, in addition to checking delivery at the expected date, the validation process–involving several stakeholders–also depends on these documents. Therefore, a streamlined validation process is also mandatory if downstream processes are to use work packages on time.

The Optimized Plant Construction **3D**EXPERIENCE provides a full set of capabilities to execute deliveries (storage of the document deliverables themselves) and their validation (workflows and signatures). Users can also create "on demand" status dashboards to give full visibility to project managers on any possible deviation (see Figure 4). The strength of the Optimized Plant Construction **3D**EXPERIENCE is to consistently handle the relationship between all aspects of a document's lifecycle: linking planning tasks of engineering document deliveries, the engineering documents themselves in digital format (text documents, PDF drawings, and spreadsheets), and the validation workflow. All stakeholders access the same single source of information, enabling visibility across key project stakeholders, with access control depending on a person's role and organization.

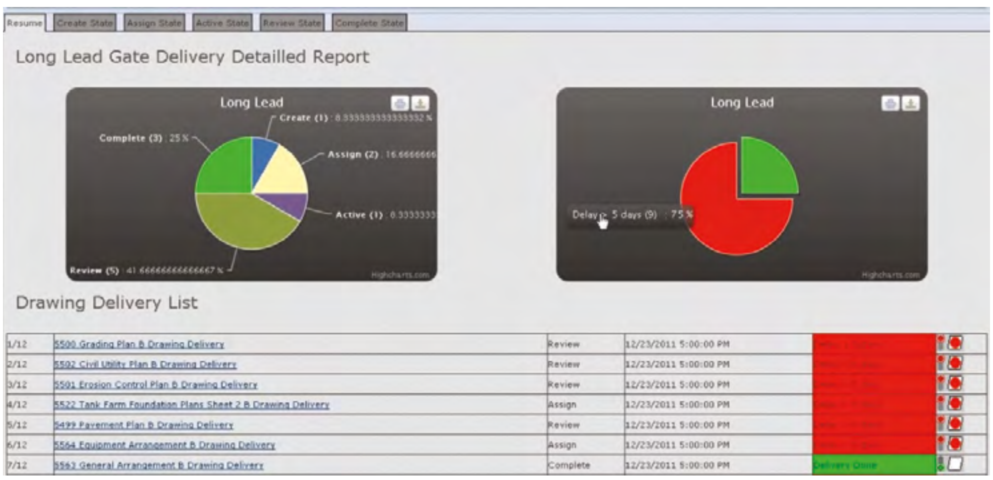


Figure 4. Dashboard for timely monitoring of engineering deliveries

CAPITAL PROJECT PLANNING AND EXECUTION INFORMATION

It is a well-known fact that information is power, or better said, it enables people to make the appropriate decisions that lead to a successful outcome or to control deviations. Historically, there have been at least two game-changing breakthroughs that have democratized information. They include the invention of the Gutenberg movable type printer and 500 years later the digital storage of computerized data. This has accelerated progress in business thanks to faster communication. Recently, business speed has increased because competition has increased due to productivity gains generated by IT solutions.

Information that is useful and meaningful in a given context is built by assembling or calculating a result from elementary data. Differences in business speed are caused by the way digital data is transformed into meaningful information. Business management involves making the right decisions with respect to initiatives and providing the correct solution to a problem. A manager, control room operator, or a car driver must track and/or react to information coming from inside and outside the organization, system, or vehicle.

Information processing is organized into seven tasks: searching, selecting (short-listing), capturing (input), storing, interpreting, communicating, and implementing. In the Energy, Process, & Utilties industry, searching, selecting, capturing, and storing information are often automatically done by software specifically written for the purpose of collecting and selecting data within a given scope. This is, for example, the case when regularly collecting power generation values of a group of wind turbines so that historical data can be derived for one individual turbine.

In PLM, capturing is often the first step. For example, capturing an incident report due to the incident's occurrence, there is no search or selection; all incidents have to be captured. Capturing, storing, interpreting, communicating, and implementing information is typically a lifecycle management process. Let's continue the example of an issue in the construction of a plant facility and see how Capital Project Planning and Execution included in the Optimized Plant Construction **3D**EXPERIENCE delivers PLM support:

- Capturing an issue by any stakeholder, for example a site surveyor.
- The system implicitly stores the information; the benefit is visibility for all stakeholders, depending on their access rights. A PLM system also notifies all stakeholders–the project manager, for example–who need to react to the open issue.
- Interpretation of the issue by a project manager helps him make a decision to solve the issue. The system links the issue and the created decisions (that are tasks to be performed) with the documents to be created. This enables full traceability from problem to solution.
- Communicating is the transfer of decisions in the form of orders of actions to other stakeholders. Tasks are assigned to people who are notified. Traceability is ensured so that the role of each person is understood. One can look at the tasks that a stakeholder has to perform or from a given task understand who is responsible, the 'what' and 'when' about delivery, what issue it may be related to, and so on.
- Implementing is the realization of the actions that will solve the issue. Information is usually also processed with a lifecycle status, for example for a document ('created', 'in work', 'delivered', 'validated', 'released', 'obsolete') and for a task 'created', 'active', 'finished', 'validated'). The system monitors the realization of the actions and alerts if delays occur.

A PLM system needs to ensure that the processing of information is properly integrated, so that valuable information is captured and supplied to the right stakeholders. For instance, it would make sense to share issues encountered during plant maintenance operations about a specific product with the members of the product development team responsible for product redesign.

Decisions range from the reflex of an automotive driver to the conclusion of an in-depth study—an evaluation based on feasibility, cost, time to implement, consistency with corporate strategy, and other criteria. But a decision is always better if it is based on the right information presented in the right form and at the right time.

- "Right information" usually means that it is precise, accurate, and complete.
    - Precision or reliability of a measure is the degree with which the results are similar for a repeated measurement performed under the same conditions. With respect to information precision, one could say that it refers to whether various people understand the information in the same way. Lack of precision leads to loss of time, people having to investigate to understand what they have to do, or leads to wrong execution of a job. The Optimized Plant Construction **3D**EXPERIENCE provides the platform on which a company can implement its processes and supervise its activity in both a global and precise manner.
    - Accuracy or validity means that information hits the target. The cost of inaccurate information can be high. For example, a contractor not getting the last version of a construction drawing may lead to a dismantling and reconstruction of a structure, resulting in loss of time and cost. Since the Optimized Plant Construction **3D**EXPERIENCE is based on a single source of the truth, in which document versioning automatically updates the document link to a contractor's task, it dramatically reduces the risk of inaccuracy.
    - Completeness means that nothing needs to be added, that the subject of interest is covered comprehensively. Complete information means there are no gaps in an end-to-end specification scenario of the construction sequence. It also helps understand specifications without ambiguity. The BOM used to procure the equipment to be installed in a given task needs to be complete; otherwise the task may be delayed if the missing equipment is only noticed during task execution. A complete BOM is, of course, initially dependent on the creator. However, completeness can be lost in further information transmission. The Optimized Plant Construction **3D**EXPERIENCE provides the ability to integrate in a "single source of truth," product definition, requisition to suppliers and task definitions, and to link equipment lists to requisitions and job tasks. This integration diminishes the risk of missing information.
- "In the right form" means presenting information in a relevant manner. Relevancy is the applicability to a specific target case depending on the stakeholder's role. Top executives and contractors have different information needs with respect to the same target case. The Optimized Plant Construction **3D**EXPERIENCE provides standard and customizable means so that each stakeholder gets dashboards and quick access to the relevant information.
- "At the right time" means information that is available when needed. Cost and value created by the activities of a long-term construction project need to be regularly available so that measures can be taken when dashboards show actual project deviations with respect to the provisional plan. More commonly, any delay in obtaining information concerning the date required for task execution leads to delays in the construction schedule. The Optimized Plant Construction **3D**EXPERIENCE provides project managers an "on demand" dashboard to track all types of deviations in the planning.

The way stakeholders understand information depends on how this information is processed and delivered in a capital project. This can range from full understanding to misunderstanding. The Optimized Plant Construction **3D**EXPERIENCE is designed to process information so that all capital project stakeholders can monitor the execution of their activity:

- With project status available in real time, the Optimized Plant Construction **3D**EXPERIENCE delivers an integrated decision support environment.
- Change impact analysis in real time helps achieve minimum waste of time, cost, and resources with an executable and reasonable plan based on the actual state of the project.

As a result, stakeholders will improve their capability to deliver the construction "on time" and "on budget," thus avoiding delay penalties and costly reworks.

3D UNIVERSAL AND UNAMBIGUOUS INFORMATION

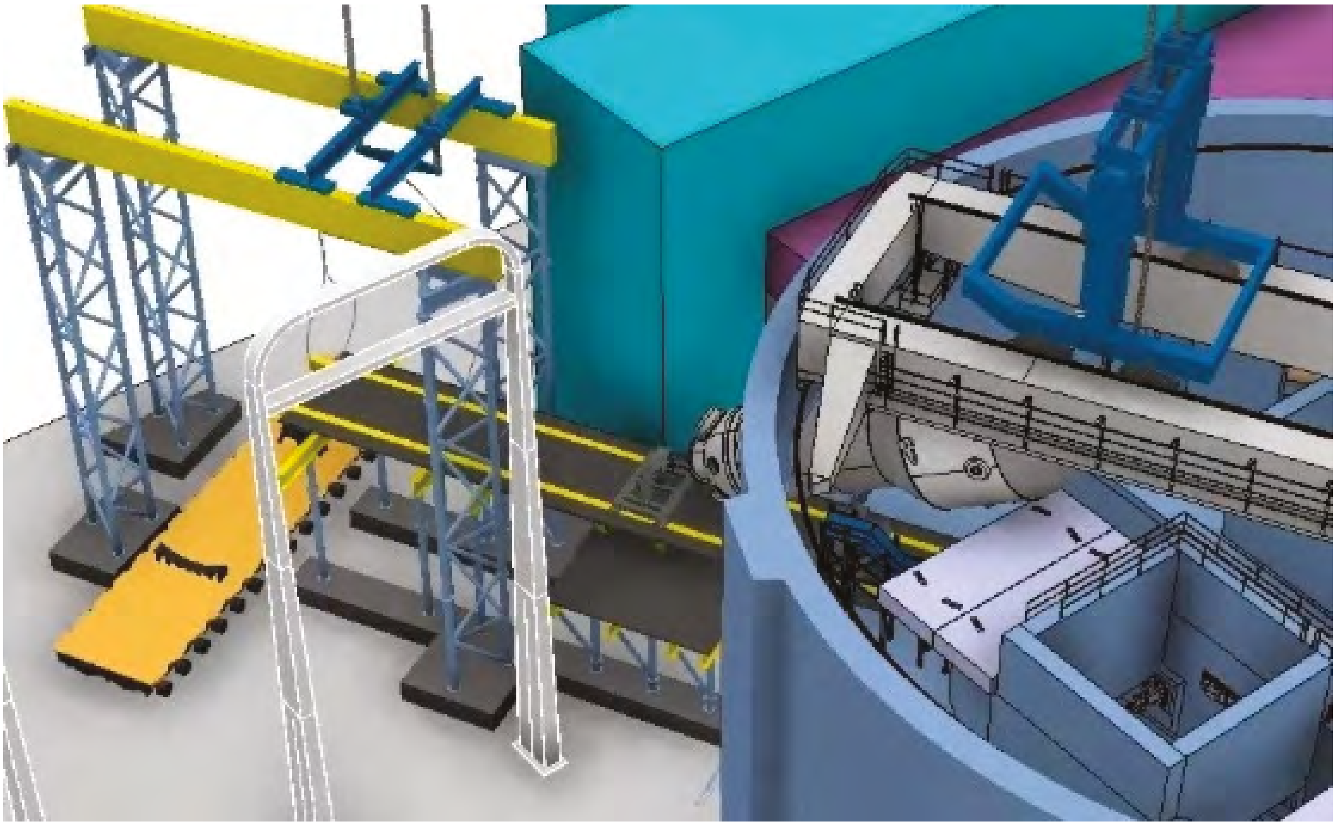
This white paper has previously discussed the subject of information quality with respect to the right information in the right form. PLM itself cannot handle quality of all project information, since it does not manage the 'inside' of a document. Documents are managed as black boxes; it is up to the creators and people who are in charge of validating them to handle their quality in terms of precision, accuracy, and completeness.

As with the "engineering work package," the engineering documents that are handled are text documents, spreadsheets, and PDF drawings. A typical objective of such documents is to correctly represent reality, or what the reality will be after construction. Drawings are an abstraction in three planar views of a realistic 3D object. Drawings are also not always complete since many things are implicit, meaning they are not explicitly designed, but left up to the contractor to decide.

The 2D form of the documents themselves renders the reality they aim to represent incomplete and is, therefore, a source of ambiguity. Their imprecision is open to interpretation by the various people involved in the project. Imprecision leads to errors that can generate further defects and incidents if not noticed immediately.

A manual and paper-based methodology for planning processes and defining schedules may be difficult to interpret, often contributing to unanticipated problems and complications. Therefore, if ambiguities are known, tasks can often be planned to take into account possible failures and retries. Workers may, for example, discover that equipment cannot be moved as planned because of interferences and insufficient safety distances. Moreover, activities in these complex procedures are not always optimized, with workers performing redundant tasks or waiting idly while other work is completed.

To increase precision, accuracy, completeness, and relevancy of information, the Optimized Plant Construction **3D**EXPERIENCE delivers 3D data access to stakeholders for certain construction processes, in addition to the official 2D legacy and product lifecycle management documents.

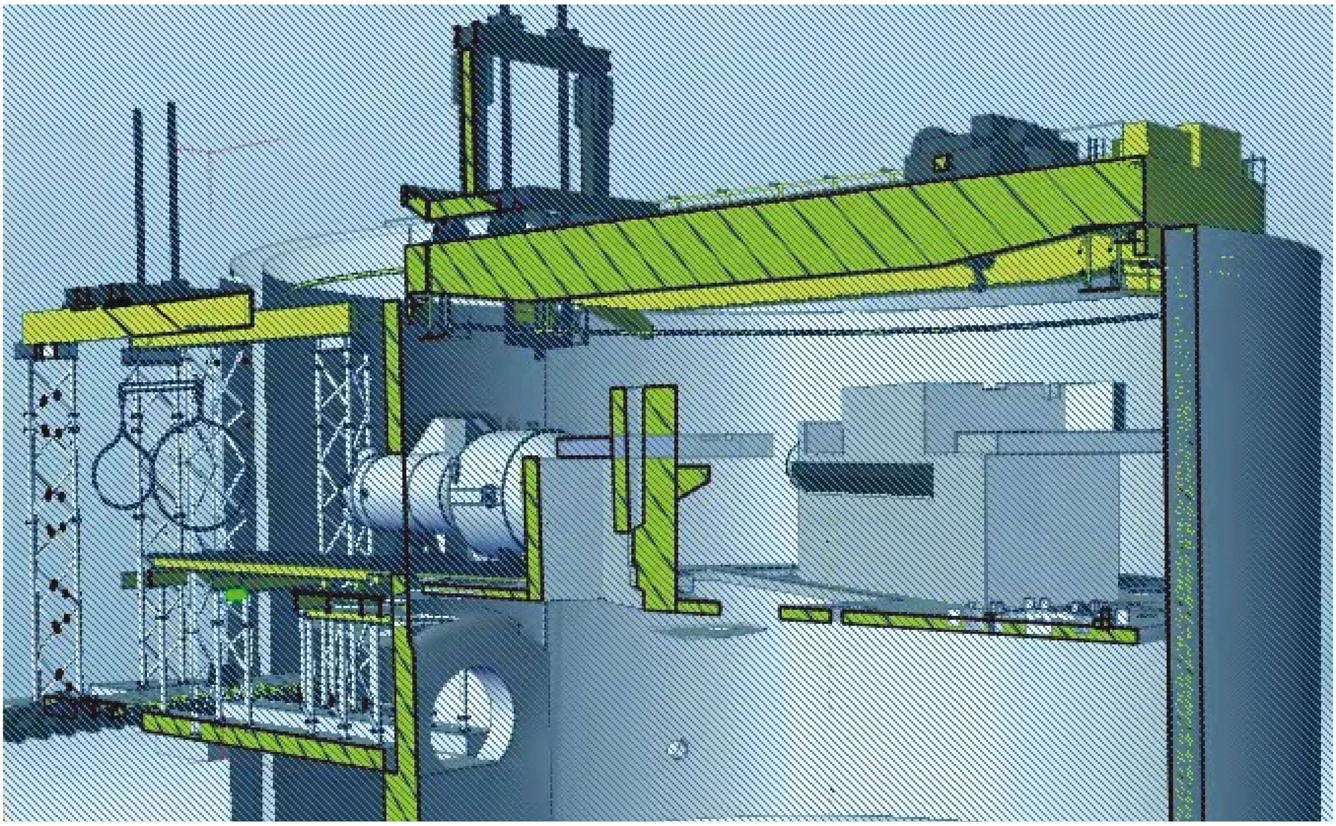


SIMULATION

With lifelike 3D models, simulations, and visualizations, planners can test their project plans virtually and workers can precisely see what they need to do before they attempt to do it on the job. In this way, optimal procedures and scheduling of operations can be worked out before projects are started in the plant. These simulations can also include lifelike models of humans or manikins for a wide range of virtual ergonomics or human factor studies. Simulations can be performed to detect clashes, for example, or determine optimal paths for installing equipment. This minimizes interferences by identifying accurate sequences that avoid having to remove structures or piping or to clear the path of other obstacles before continuing with the installation. The 3D system also provides visual alert notices during the simulation, and detailed clash reports listing interferences. In this way, engineers can study and modify motion paths until a feasible plan is determined. Likewise, the kinematic motion of cranes, robotics, or other equipment can be accurately simulated to check that the devices can perform the required operations and to optimize their positioning. In addition, a company's valuable know-how and intellectual property (IP) can be captured and retained in the 3D environment for planning of a future project. It becomes possible to accurately predict how people and machines will interact on site and the stress that each will experience.

Such capabilities to simulate and assess these scenarios can also help companies achieve "zero incidents" and potentially avoid on-site worker injuries and associated losses. Linking the master schedule to the 3D work breakdown structure (WBS) and the 3D process simulation model creates an animated, time-based 4D representation (3D plus the variable of time) that enables users to more easily visualize and understand operations and timelines.

3D-based simulation systems provide an effective way for engineers to develop precise and detailed plans to execute work "right the first time" by studying various scenarios and performing what-if evaluations well before tasks are attempted with actual equipment. The ability to digitally plan and optimize processes lowers the risk of mistakes, delays, and rework, and increases overall performance.



PROCESS AND ASSEMBLY INSTRUCTIONS

Because the execution of a project greatly depends on project cost, construction contractors need to have a better understanding as early as the planning and design stages.

Modern 3D instruction software improves this understanding by delivering an animation of the step-by-step construction sequence, or an explanation of a recurrent and standard task (like the construction of a wall or excavation work). The objective is to teach, in an efficient and safe manner and with a high level of quality, the way to perform repetitive tasks, such as assembling a pump on a line, or ensuring first-time success of a complex assembly sequence, such as the introduction of a big heat exchanger in the reactor unit. 3D interactive instructions minimize the need for textual explanations.

CONCLUSION

Collaboration and information sharing between stakeholders primarily requires a common project management and execution system to deliver a single source of the truth.

It is accessible for all stakeholders, providing visibility to key project stakeholders, with right access controls depending on a person's role and organization. Since project status is available in real time, it delivers an integrated decision environment. Change impact analysis in real time minimizes waste with respect to time, cost, and resources with executable and reasonable plans based on the actual state of the project.

3D plant synthesis provides a common 3D universal language for communication resulting in a clear understanding of complex plants.

Correct assembly sequences are defined upstream concurrently with engineering design in a virtual construction 4D simulation before they are documented, ensuring right-the-first-time assembly. Work schedules are not only validated as achievable before they are released to installers, they are done before a design is too advanced and assembly problems cause delays and additional costs resulting from engineering rework.

Engineering, procurement, simulation of construction, and commissioning are all integrated for optimized planning and execution, and maximized intellectual capital.

END NOTES

1. *Source: Booz Allen Hamilton Capital Project Execution in the Oil and Gas Industry; Increased Challenges, Increased Opportunities*

2. *Source: : Thesis of Tim Slootman, Enschede, January 2007*

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