WHITE PAPER

Lean Construction

Technology Advances in Lean Construction

INTERGRAPH®

Contents

1. Introduction

We hear the term “lean” used very often today, usually associated with lean manufacturing, lean thinking, lean production, and lean construction. There are many arguments and debates on what each of these have in common, or what their differentiators are. The single undeniable similarity is that they all use the word “lean”.

So, what does “lean” really mean?

The word “lean” has many meanings and uses. One meaning is to minimize and eliminate waste, which is a common definition of the word. However, it is not what is eliminated, but added, that is the most defining denominator: value.

Another use of the word “lean” is to sway towards an opinion. This definition may be the most applicable for the industry use of “lean”, as a common factor in all lean thinking, ideas or principles, is that it requires adopters to “lean” or sway a new direction, and change their mindset and philosophy.

This white paper will explore lean construction and how advances in technology are making implementation of lean construction practices achievable for the industry, with core functionality built into the products as standard out-of-the-box features. By embedding these lean principles in the software, technology is creating lean tools that will become a major differentiator in shifting the construction paradigm, and delivering maximum value to the industry.

2. Origins of Lean Construction

The Japanese automaker Toyota adopted a change in philosophy in the 1970s that changed the way the world would approach production. Toyota was the first – or at least the most notable – organization to bring "lean principles" into the limelight. Toyota created a focus on eliminating waste to improve customer value in the automotive industry. The small Japanese automaker grew to be the world's largest by adopting seven waste reduction principles in its production manufacturing, and preserving value with less work.

Toyota's new production philosophy of focusing on waste elimination was expanded to include improved efficiency by optimizing workflows, and came to be known as "lean manufacturing". Today, lean manufacturing is practiced by most of the major manufacturing companies worldwide, and is causing an emerging "lean movement" in other industries.

Lean manufacturing was a major influence on lean construction. Although the term "lean construction" was adopted nearly 20 years ago, it is still trying to gain the momentum in the construction mainstream that lean manufacturing currently has in the manufacturing industry.

If you look back at lean manufacturing, it was a considerable time before the lean principles were in the mainstream of manufacturing as well. However, if you look at the evolution in the construction paradigm, you can see a slow transformation; lean construction is a natural transition for that to emerge into the mainstream.

The original construction paradigm was cost and schedule. For ages, it had been focused on getting it done fast and cheap, usually at the expense of one or the other: accelerating schedules would inevitably escalate the cost, while forcing cost reductions usually extended schedules.

There have been some interesting factors that have influenced the construction paradigm over the years, such as safety and quality.

When regulatory and humanitarian pressures made safety a new project driver, it was first believed this would have an enormous negative impact due to new safety laws and regulatory agencies adding cost and delaying projects. Instead, as owner operators embraced the idea and insisted on implementing high safety standards, a shift took place in the paradigm. Contractors saw a reduction in accidents, lower insurance costs, and a decline in workers' compensation, with productivity back to previous levels and later increasing. Owner operators and contractors realized that safety mitigation was an added investment in time, money, and resources, but it also saved time and money. Enforcement was a smart idea because it produced a great return on the investment required: it had value.

The same was true for quality. Poor quality caused customer dissatisfaction through rework, delays, and cost overruns. Investments in quality assurance programs, people, systems, and controls improved workflows and added value.

Lean construction is a new paradigm in construction planning that uses lean concepts that approach value rather than cost, and efficiency rather than schedule.

> *Lean Construction, as defined by the non-profit Lean Construction Institute (LCI), is a production management-based project delivery system, emphasizing the reliable and speedy delivery of value. The goal is to build the project while maximizing value, minimizing waste, and pursuing perfection – for the benefit of all project stakeholders.*
>
> Lauren Pinch, *Construction Executive*, November 2005

Owner operators are the main stakeholders in construction projects, and it would be remiss not to recognize that cost, schedule, quality, and safety are the key drivers behind their project approval and funding.

The best way to achieve that value is to incorporate lean practices into early planning before the project is approved. Collaboration must be achieved with the owner operators; engineering, procurement, and construction companies (EPCs); and all project participants to build these lean principles as early as possible in the conceptual stage.

Looking back, we see that lean manufacturing revolutionized manufacturing by eliminating waste and improving value. We see that improving quality raised customer satisfaction and eliminated rework. We see that improved safety not only fulfilled a humanitarian obligation, but also showed improved efficiencies in workflows with cleaner work spaces. A common factor in all of these is that they all were smart ideas.

If you plan with lean ideas, you are planning with smart ideas. Lean construction is not about thinking fast and cheap; it is about thinking smart.

3. Lean Construction Principles

Lean construction is a “way to design production systems to minimize waste of materials, time, and effort in order to generate the maximum possible amount of value”. (Koskela et al., 2002)

Value in construction is like value in any business: it is a return on your investment. Adopting lean principles is an investment in the future of the project, which will reap benefits and give a solid return on investment.

- Improve communication planning with owner, work force, contractors, and suppliers with visualization and open display of schedule, design, and workflow
- Eliminate waste of materials, poor communication, duplication of efforts, and design errors
- Improve work planning by early planning, with a focus on improved workflow, achievable tasks, distribution of workload, and a clearly defined work scope
- Look-ahead scheduling with just-in-time deliveries, engagement of all parties, availability of resources, access to site, and coordination of other dependencies
- Plan and coordinate off-site fabrication and modular construction activities to reduce site congestion, distribute workload, minimize field work force, and improve just-in-time delivery
- Create a clean, safe, and efficient working environment, and communicate safety

4. Advancements in Lean Construction Practices

Technology will be critical in the advancements of lean principles in construction. Computers have played a key role in improving project performance for many years now by increasing the speed, accuracy, and quantity of data that can be processed. New software is constantly being developed that can improve the focus of principles, practices, and paradigms in construction, such as lean construction.

Today, software with preconfigured rules can bring lean practices to the project workflow:

- Eliminate human errors
- Prevent duplication
- Reduce inventories and eliminate surplus
- Create real-time data link with instant updates
- Improve communication with visualization in 3D and animation
- Allow modular design and construction
- Enable material deliveries to be just in time
- Work planners link to the 3D model, schedule, materials, drawings, and documents while building work packages

These are just a few of the many benefits that software can bring to advance lean principles in lean construction. Technology not only makes lean principles more possible, but more portable as well, with portable computers, kiosks, and other tools that bring communication directly to the workplace.

5. Work Package

A work package is a detail-level description of construction work that a foreman and a crew can perform in a scheduled amount of time. Here are the features of a work package:

- **Work package information** – detailed information that defines a work package
  - **Work package number** – sequence of numbers and/or letters that define a work package
  - **Description** – brief statement that describes a work package
  - **Status** – status for work package
  - **Construction work package (CWP) number** – number identifying the CWP of a work package
  - **Engineering work package (EWP) number** – number identifying the EWP of a work package
  - **Contractor** – name of the contractor associated with the work package
  - **Discipline** – craft discipline of the work assigned to a work package
  - **Purpose** – plan or function of the work package
  - **Design Area** – name and number of the design area of a work package
- **Work package picture** – identifies a work package by its discipline (illustrated below in Figure 1)
  - If a discipline is not selected for a work package, the work package displays a default picture

Figure 1: A picture is displayed to identify the work package by discipline.

- **Work package command buttons** – deletes, saves, or closes the work package

6. Workflow

Software such as Intergraph® SmartPlant® Construction uses technology to help manage your project better and the data associated with it. SmartPlant Construction users are able to create work packages detailing work to be executed with engineering, construction, and design data stored in a database. Users are also able to view, navigate, and filter 3D models and 2D drawings that were published to the database. The SmartPlant Construction workflow allows users to share engineering, construction, and design data among engineering products and users. SmartPlant Construction is configured to provide a comprehensive electronic data storage, exchange, management, and integration system.

An open API provides direct integration with other non-Intergraph applications, such as material, project control, or schedule systems.

The workflow process allows the following:

- 3D design and construction planning can work together to make delivery, support transparency, and maximize value
- Engineering, drawings, materials, schedule, and planning are linked “real-time” to improve performance and monitor results
- Work packages created using work breakdown structure (WBS), as illustrated below in Figure 2

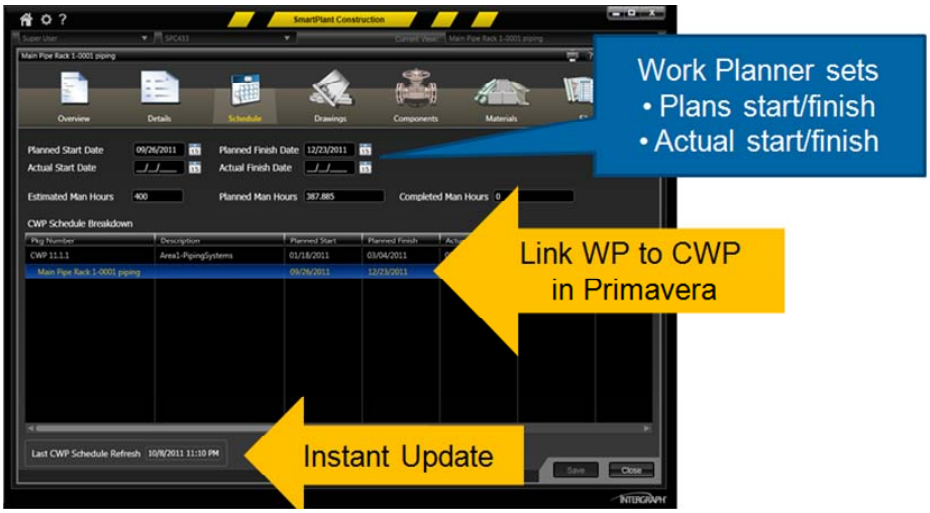

Figure 2: SmartPlant Construction enables work packages to be created and linked for a clear workflow.

7. Smart Technology Features for Lean Construction

7.1 Visualization

We retain 10 times more information visually than through written instructions. Increased visualization communicates key information to the workplace in which it will be retained. Workers not only remember the workflow and other key elements, but are also confident in executing as a result. Figure 3 below is an example of a 3D model for increased visualization.

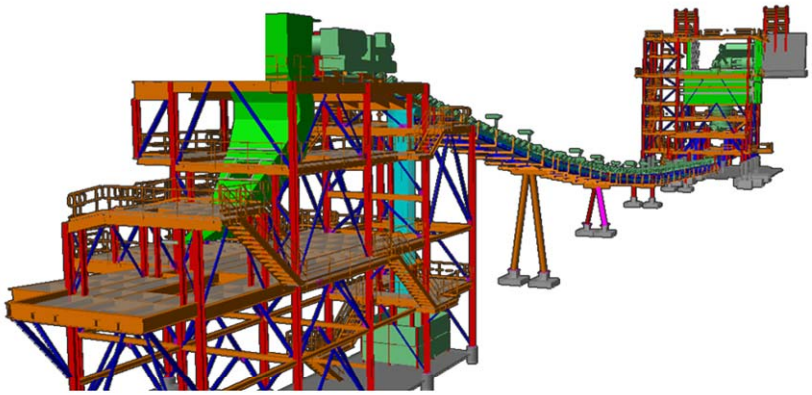

Figure 3: This 3D model helps to increase visualization.

Take “snapshots” in the 3D model to visually communicate workflow, show constructability, or flag workplace hazards. Visually show workers areas of the project to avoid, or annotate those snapshots (as illustrated below in Figure 4) with notes of caution such as “handrails that are not welded”, “access that is closed”, or other instructions.

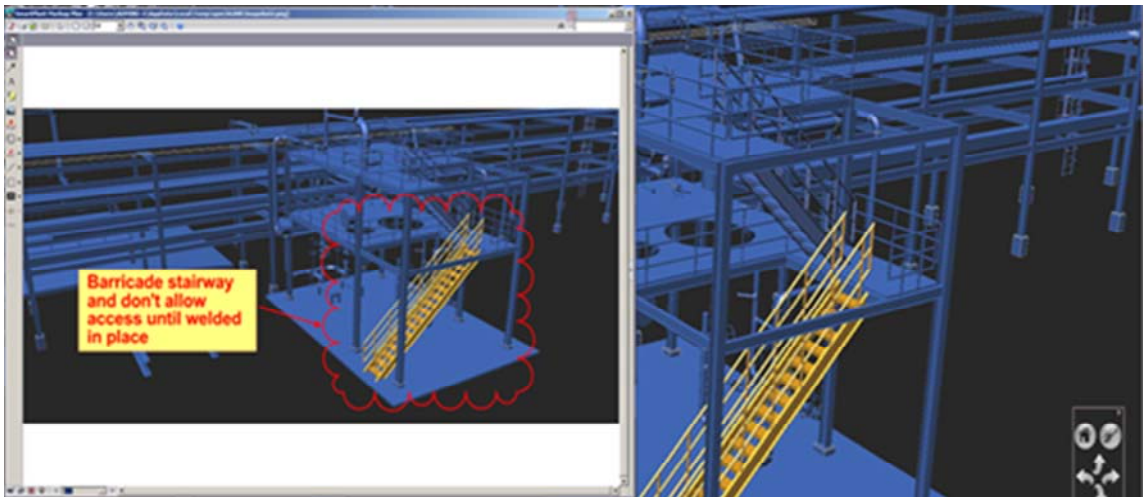

Figure 4: SmartPlant enhances the safety of a project through visualization for clear safety communication.

7.2 Look-ahead Scheduling

When construction planners constantly focus on the end date, they lose sight of the current opportunity for improvement by focusing the work taking place in the next few weeks. Lean construction planners think smart, and do not lose the opportunity to view workflow opportunities for improvement. A “look-ahead schedule” allows the work planner to see work packages scheduled to start in the next few weeks, and enables planners to efficiently prepare and communicate workflow processes, just-in-time deliveries, and resources to the work force. This facilitates engagement with others and coordination of dependencies.

As shown in Figure 5, software SmartPlant Construction will filter work packages to provide a standard out-of-the-box, look-ahead schedule selection for work scheduled in the next week, three weeks, or eight weeks. It also provides controls allowing planners to see work packages planned for selected start and finish dates with an adjustable sliding date control. Planners can see all work packages within a selected range of dates.

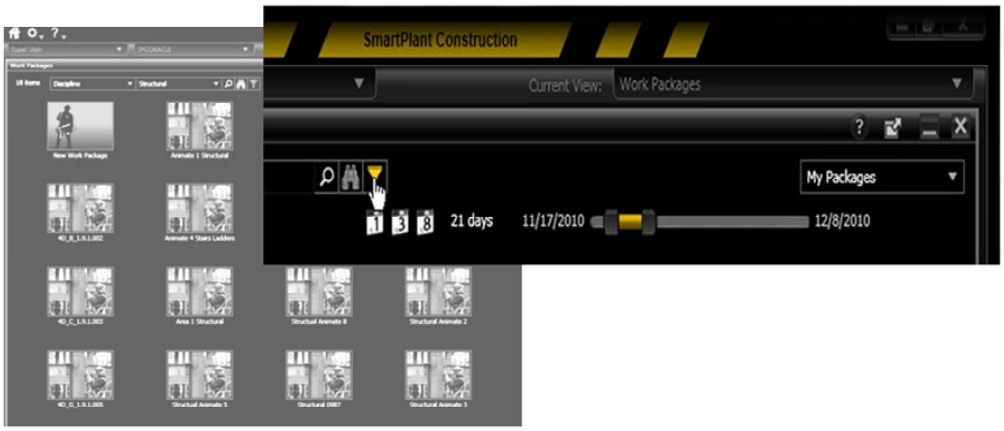

Figure 5: SmartPlant Construction enables look-ahead scheduling for work packages.

Work planners create a work package and assign sequenced work steps and components, which are then linked to the WBS schedule and material management system. Work packages can be reviewed in the look-ahead schedule, and animated in the 3D model to verify if conflicts, resources, or constraints prohibit planned execution. It can also help to illustrate if adjustments need to be made to maximize efficiency.

7.3 Prevent Planning Errors

Preset rules prevent work planners from putting components and drawings into work packages that are the wrong disciplines, or already in another work package. Predetermined limits and authorities are set with these rules, which give work planners warnings or prevent any action. Figure 6 shows a planner trying to drag and drop equipment into a cable tray work package and receiving an error warning, which prevents costly errors and eliminates wasted rework.

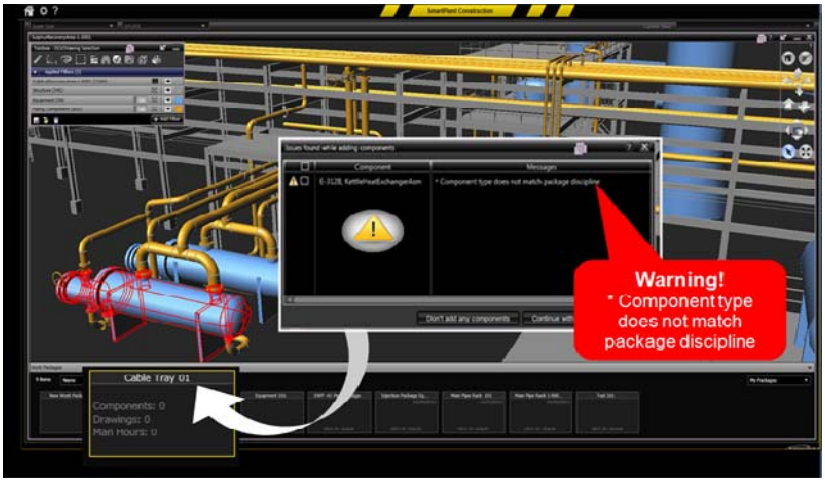

Figure 6: SmartPlant Construction's rule-based technology prevents planning errors.

7.4 Powerful Filtering

SmartPlant Construction has powerful filtering capabilities that enable work planners to search the 3D model and only select work that needs planning, eliminating wasted time from searching all work. The rules of progress in the Intergraph software allow work planners to efficiently drag and drop components and drawings, and load them into work packages, which automatically calculates the man-hours (as shown in Figure 7 below) and the number of components and drawings.

Figure 7: SmartPlant Construction provides automated man-hour calculations.

7.5 Rules of Progress

Preconfigured rules of progress will computer-generate work steps as components are added to work packages, eliminating wasted man-hours (as shown in Figure 8 below).

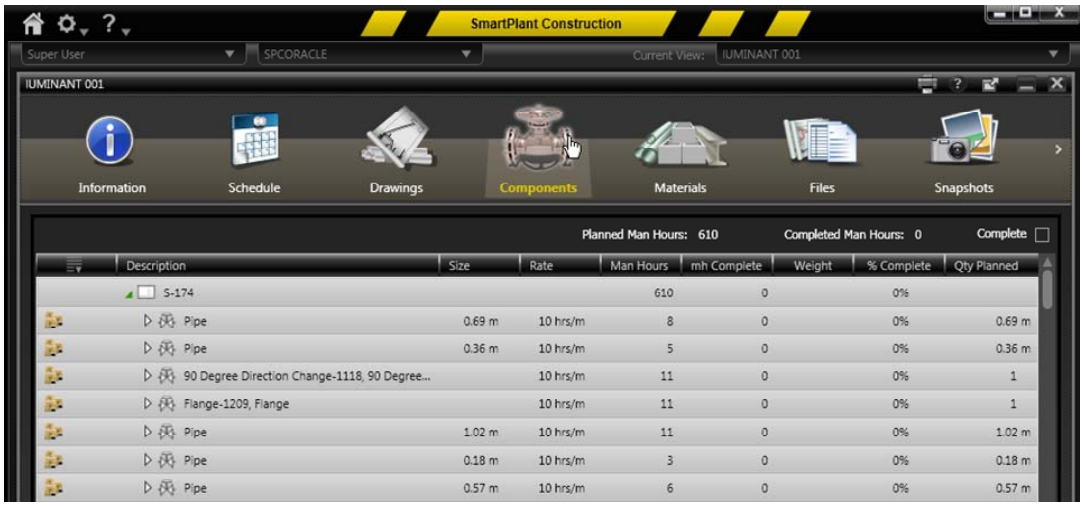

Figure 8: SmartPlant Construction can generate work steps for the most efficient use of man-hours.

7.6 Just-in-time Deliveries

Figure 9 illustrates how work planners can view material forecast and make reservations directly from SmartPlant Construction. Material availability can be sorted by tag number, drawing, or commodity code. Material location and estimated time of arrival are known in “real-time”, with direct links between the material management system, schedule, and SmartPlant Construction to enable “just-in-time” deliveries. This eliminates waste and shrinkage, and prevents delays as well.

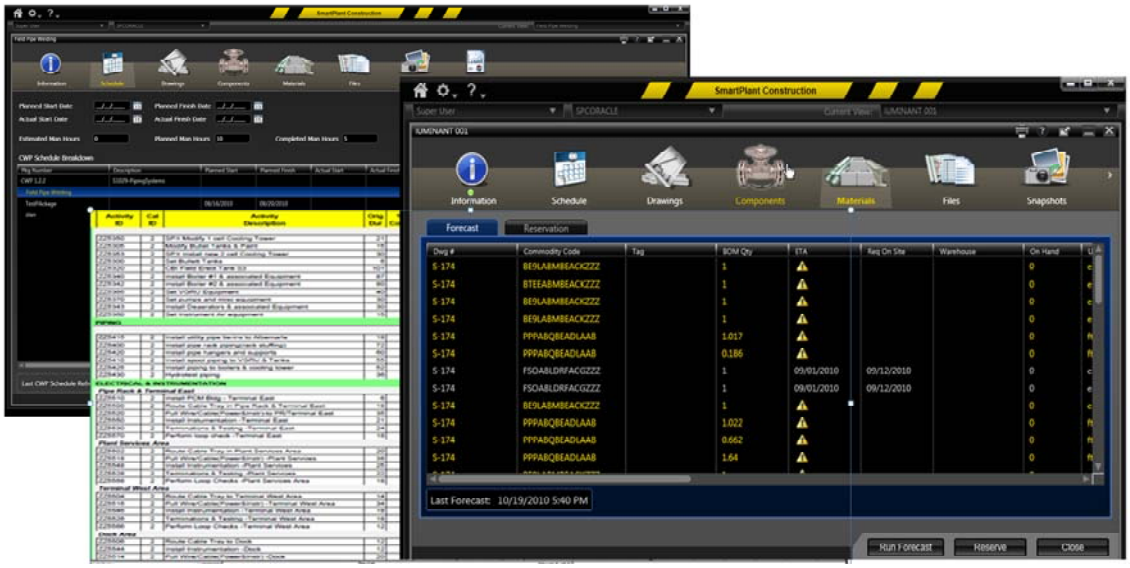

Figure 9: SmartPlant Construction enables work planners to view material forecast and make reservations directly for just-in-time deliveries.

7.7 Modular Construction

The ability to create modular designs in 3D and develop work packages to manage these allows for increasing offsite work and brings value to construction planning. As shown below in Figure 10, SmartPlant Construction enables modular construction, and the user is able to manage the work

packages for those specific modules. Modular construction is usually performed in controlled environments with lower labor rates that are highly productive, and can be staged and sequenced for just-in-time deliveries, eliminating site congestion, reducing site labor, and shortening schedule durations.

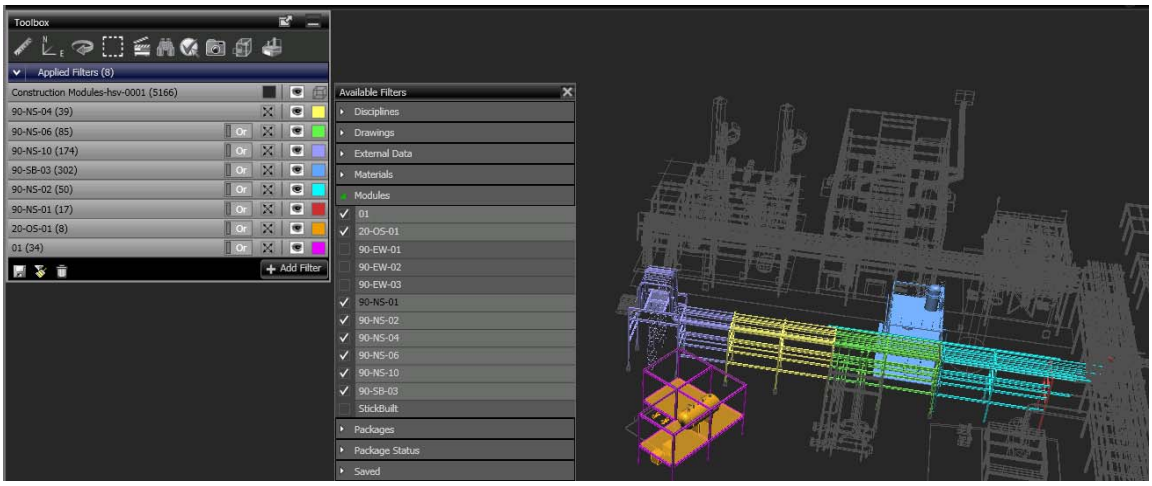

Figure 10: SmartPlant Construction enables modular construction, and the development and management of work packages accordingly.

7.8 Animation in 4D

The ability to animate the construction workflow allows work planners to identify conflicts and correct them before errors or delays occur (illustrated in Figure 11). It also helps visualize the constructability of the project and communicate the workflow process, site access, and animates the work sequencing and schedule. As the saying goes, “a picture paints a thousand words”, and the 4D animation is able to communicate what needs to be built and where.

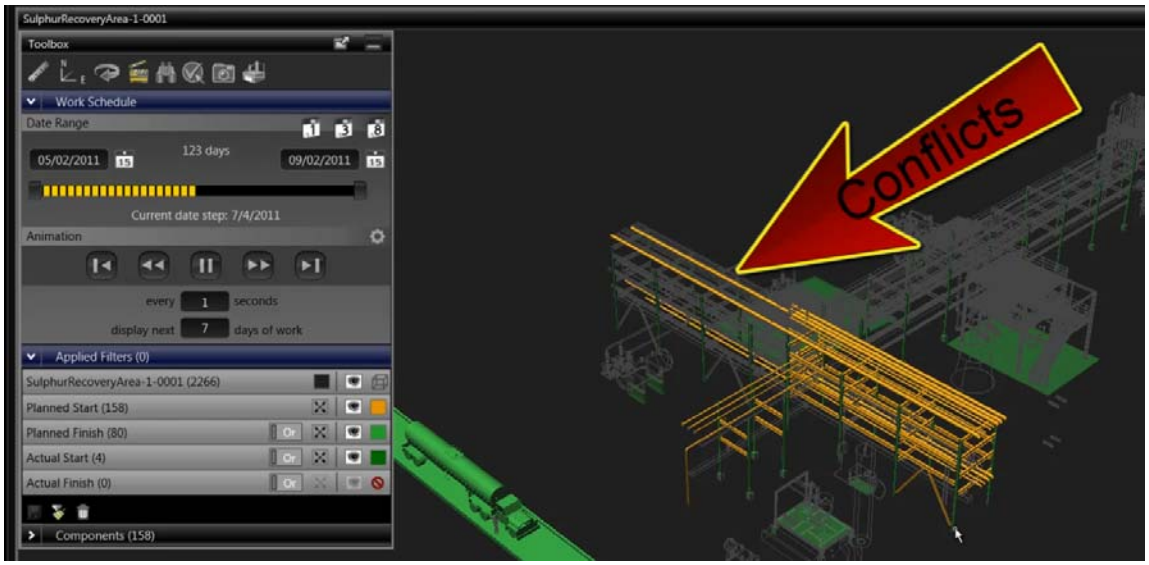

Figure 11: SmartPlant Construction features enhanced 4D animation, enabling work planners to identify and correct conflicts early in the planning process.

You will also be able to adjust variables and visualize totally new scenarios, and see the impact on the plan before it happens. This maximizes value, making construction both safer and more efficient. As

delivery times shift, vendors send through information onto the shared system and the impact can be clearly seen, allowing for a solution to be worked out. If materials do not arrive at a particular site, the workers know that a certain work package cannot be completed, so they can then consult the model and look to see if parts are available elsewhere on the site to help them complete the job. Construction people will know what is on site, what can be built, and when future deliveries will arrive, which all enable proactive planning.

7.9 Prevent Double-planning

Preset rules prevent work planners from double-planning work that has already been planned, or from using the same components twice. Figure 12 below shows a planner trying to drag and drop components into a work package and receiving an error warning, indicated that these components have already been planned in other work packages. This prevents ordering excess material and causing wasted surplus, as well as eliminating wasted time and rework.

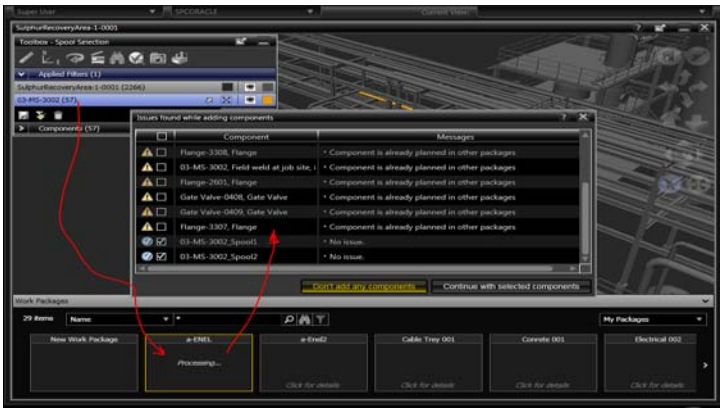

Figure 12: SmartPlant Construction prevents double-planning of components across multiple packages.

7.10 Notice of Change

A great deal of waste on projects is caused from unnecessary rework using incorrect drawings, or crews standing idle while searching for latest drawing revisions. Technology allows automation of the change notice process, which can be enhanced further by giving notice to the specific work package affected by the change (illustrated below in Figure 13).

Figure 13: SmartPlant Construction enables automation of the change notice process, marking clearly the affected work packages.

7.11 Internationalization

Today, we have suppliers, engineers, contractors, subcontractors, and projects around the world. The need for strong communication in a common language is greater than ever. With improved technology, visualization is the strongest form of communication breaching the international language barrier; however, the written word is still relied upon in certain instances. As illustrated below in Figure 14, SmartPlant Construction enables a homogenous or heterogeneous environment, allowing regional settings to be changed to multiple languages, such as Chinese, Russian, Portuguese, or other languages, which can be viewed simultaneously around the world. This eliminates problems, errors, and wasted time caused by misinterpretation, or failure in communication that breaks the workflow.

Figure 14: SmartPlant Construction is available in multiple languages.

8. Lean Construction: The Future

Lean construction may just be an attitude or way of thinking currently, but it is gaining momentum in the industry, with a trend towards incorporating lean construction principles into standard workflow processes. This may be difficult to accomplish but more and more owner operators are interested in the concept.

In the end, like many other industry practices, if lean construction is to replace standard traditional practices, it will require owner operators who fund the projects to find new ways to push lean principles and shift the construction paradigm.

SmartPlant Construction is the next-generation software that is built with lean principles featured as standard out-of-the-box functionality. It brings advanced technology to the workflow process by putting “lean” tools directly in the hands of work planners, and embedding a lean construction culture directly into the project planning and execution.

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