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Executive Summary

Modern marketing rhetoric claims that, in order to cut out expensive costs and reduce risks during the design and construction phase of major capital projects, we must ensure that the plant design is completed ‘right first time’. If we can eradicate the iterations and reworks in design and form the design right from the outset, we will ensure that everyone in the project execution is equipped with the latest and most accurate information about the project. This business paper challenges that premise and argues that, in many instances, ‘right first time’ is not achievable. This ideology does not have the flexibility needed to cope with client, legal, contractor and environmental changes which influence scope changes throughout the project.

The confluence of design theory and design development, the reality of construction and extremely complex engineering, requires an acknowledgement that iterative and evolving design is an important concept. We focus on the concept of the ‘Design Spiral’ for complex, multi-discipline problem solving and we argue that the key to Engineering & Design for Lean Construction is taking control of this spiral, reducing the iterations and building better communications between the designers and the constructors. Evolutionary design, just as in nature, requires the design process to be adaptable to change, and allowed to cycle through alternatives as quickly as possible until its most ideal form is achieved.

‘In many instances, “right first time” is not achievable. This ideology does not have the flexibility needed to cope with client, legal, contractor and environmental changes which influence scope changes throughout the project...’
**Right-first-time Nirvana**

It is widely advocated that engineering contractors and construction contractors should aim to produce the right information for their designs first time. Why waste time reworking designs when they can be created from the outset to be correct? It is those same reworks which add risk and often unforeseen costs to the project, so it seems that eradicating them should be the primary drive to reduce risk on projects.

The logical conclusion is to then make sure that the plant design and engineering is completed ‘right first time’.

Evidence is easy to find of projects which have struggled with an ever increasing level of complexity and mounting costs as small issues evolved into bigger and more significant problems. Many of these cases indicate deficiencies in the management and communication of the right information (it all helps to fuel the vision that all that is required is to ensure that decision-makers are presented with the right information) and this right information should be available at the first time of trying.

This is a very attractive vision, but the realities of a real project present too many obstacles to achieve it.

There are countless different influences over the project duration which will affect the selection of design:

- **Design development** – One of the most frequent changes which occur during design is the natural evolution of the design concept through layout and detailing. Original design specifications can be solved in many ways; factors such as parts availability, supplier specifications and budget can affect the evolution of the original design.

- **Client changes requirements** – New specifications, output requirements or product options are introduced by the client during the design and construction phase.

- **Contractors disagree on design** – Lack of clarity in design ownership through poorly specified contracts introduces design conflict and even litigation.

- **Out-of-sequence design information** – The parallel nature of design, fabrication and construction can lead to old or incorrect engineering information being shared within the project. This often results in ill-informed conclusions and decisions.

- **Decisions made based on data with unknown status** – Information where the status or maturity of the information is unknown can be used inappropriately (e.g. data which is provisional being used to make buying decisions).

- **Data errors** – Errors occurs from miscommunication, oversight or unchecked work which percolates through the design process and can significantly affect construction.

- **Accommodating site changes** – Wrong or late deliveries of materials, site incidents and weather delays can all affect the evolution of the original design.

Is it possible for a design which is ‘right first time’ to weather these different influences?
Nature of the business

The project execution organisation is a disparate team of companies, cultures, skills and individuals who come together to meet the goals of their client, designing and building vast and complex plants. Inevitably, the design and construction phase is as compressed as the client can get it, in order to minimise the period where capital expenditure is not being returned and to move to profitability in the shortest time. In order to meet these deadlines the EPC and subcontractor community have to work together as efficiently as possible, and some very challenging parallel working ensues.

This compressed timescale leads to parallel working within the project, whereby the construction of the plant very often starts at a time when the design has not been completed. The teams and disciplines work in parallel to tight schedules and each must stay abreast of the progress of the others. This parallel working would be easily managed if there were not so many interdependencies in their outputs and design processes. For example, changes enforced by a process engineer may affect the bore of pipework which, in turn, affects the pipe support design, which may affect cable tray positioning, and so on. Different design disciplines are all affected by changes to each other’s designs.

Many of these changes are needed to evolve provisional data and are early assumptions, rather than changes invoked by a new design requirement. For example, when the process team identify the need for a pump, the mechanical, electrical and layout teams may all make assumptions about the size, spec and power requirements of that pump. As the design develops, this information will be refined, but it will only become definitive when the pump vendor has been selected. In the meantime, all disciplines have to work with the best available data.

The volume of changes in design at this early phase is very high and business processes need to be streamlined to avoid overhead. This speed and agility to change the design must be counterbalanced by a level of rigour to ensure that all changes are shared and recorded. Heavyweight change management processes are too cumbersome to keep up with the rate of change.

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The Design Spiral

As design information is created, it needs to be shared across other design disciplines and across contractual boundaries to make sure that the project progresses to schedule. This process is not a linear sequence by nature; design information does not simply pass to the next team until it is completed. What typically happens is that the information iterates around a number of design teams, all affecting each other’s design. At this stage much of the data is provisional or based on working assumptions, so changes happen regularly and must be embraced and adapted to. The design process is actually more like a spiral, where information cycles ever closer to a final outcome over a number of passes. AVEVA terms this ‘The Design Spiral’.

The Design Spiral is commonly used by most of the world’s largest EPCs as the key business process for taking new designs through their phases of maturity to the constructed form.

Given the speed at which change occurs, it is easy to see how this spiral can become very challenging to manage. How do all stakeholders in the project know what stage the design is at and what version or revision of information is being shared?

Many different issues and versions of the same data and documents can be in circulation at any one time, and understanding what has changed on each revision is often the source of mistakes. This, in turn, frequently leads to bad design decisions.

Often, the design is in a state of constant flux, where changes can come from many sources. No time is available to create change notes or change orders, so a formal change management process is very hard to implement and operate in a streamlined manner.

To compound all of these challenges, the project is often being undertaken by multiple parties who are each committed to just their own contractual obligation and no more. Operating the project across multiple languages, time zones, management cultures and contractual regimes makes the management of this rapid design spiral essential, but it also makes it incredibly challenging.

Organisations who are able to control the design spiral and rapidly and accurately communicate change will be the most effective during the design phase of project execution.
Engineering & Design for Lean Construction

In this context what does ‘Lean’ mean? Many interpretations, documents and management models have been created around the Lean Manufacturing model which AVEVA believes can be articulated in three key principles of the philosophy:

1. Respect for people
This means empowerment at all levels of the organisation, from the senior management team all the way through to the ground workers. Being accountable for your work and being empowered to improve the efficiency of your working practices. Unified adoption of the philosophy is essential to its success.

2. Eliminate non-value-adding activity (remove wastage)
Adopting zero tolerance to wastage, whether material waiting, in transit or in storage, or time spent reworking something which was wrong. This also means having little or no inventory of parts and no stockpiling.

3. Maximise the efficiency of value-adding activity
This means continual improvement in the efficiency of producing parts. Value-adding activity is defined as work which is performed on a part. In the power and process industries this ‘part’ may be, for example, a skid unit, a spool or a whole module.

The most important influencing factor for the effective execution of lean plant design is the integration of the teams and disciplines.

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Controlling the Design Spiral

Lean construction requires these three basic principles to operate throughout the project, not just in the construction phase.

Engineering, design and fabrication practices must also be tuned to deliver in a lean manner.

Lean construction practices focus heavily on minimising wastage, and on the management of materials and fabrication on the construction site. Clearly, identifying cost sources and eliminating them with new lean processes can have a significant impact on the final costs of the project. But to focus on this alone is to overlook the role that Engineering & Design plays in the success of a project.

While the design spiral has developed as a natural response to the need to solve complex problems of plant design, it is also a source of challenge to the business. The fundamental key to lean practice across the Engineering & Design teams is to be able to control the design spiral, ensuring that the huge number of design changes are properly managed and shared effectively across the multi-disciplinary team. So, how do you control the design spiral?

AVEVA believes that there are some basic principles that need to be in place.

All disciplines take part
Integration of this design spiral as a common process across all design disciplines is essential. Coordinating half of the team’s effort defeats the point. For control to be effectively executed, each engineering discipline must be part of the same integrated approach to engineering. Respect for people is shown by making sure that all design disciplines appreciate that they operate as part of a multi-disciplinary team and are to be able to confidently share information with their peers in different disciplines.

Pervasive integration
Since the volume of changes is so high across the multiple disciplines, integration must be as ever-present as possible, and not a process which complicates or adds overhead to the process. Each engineering author must have access to information from within their working environment so that coordination and control of design information is embedded into their daily working practices and available at their fingertips.

Efficient design practices demand that this integration must be at the design object level and universal across the authoring applications, rather than simple integration based around the transfer of drawings or model files between systems.

‘Lean construction practices focus heavily on minimising wastage, and on the management of materials and fabrication on the construction site...’
Common nomenclature for ‘status’
In order for all engineers involved in the project to understand the appropriate usage of the data/information they have been given, it must be presented with a commonly agreed meaning for its status. In addition, a common understanding of what has to be completed for a certain status to be achieved must be agreed – a status checklist. It is essential that each engineer is able to immediately understand the status of the information so that they can select appropriate actions to apply to it.

Knowing where you are in the design spiral and knowing when the data you are working with is provisional or approved is a key element of design efficiency.

Each engineer must see changes quickly
All engineering information authors and review teams must be able to easily see design changes over time. Being able to track the changes made within each discipline is essential to ensuring that every contribution to the design is up to date and that changes are clearly visible.

It is important that the engineer has the ability to control whether to take on new changes and not have them mandated. For example, making a change to the dimensions of a major item of equipment should not automatically percolate through the system to all engineers, because each engineer must be able to have issued and working data. Not all impacts and outcomes of a single change can be properly assessed without each discipline engineer’s input.

Each discipline must be able to compare and update
The ability to see the work of other disciplines is not enough. To be able to inspect it and then make a selection to update one’s own information is the key to maintaining consistency across disciplines. Changes which have been made to the design by another contractor must be easy to review before updating. This is the quickest way to trap and manage changes within each team.

Access rights must be in place
Large projects create designs which cross many contractual boundaries. The ability to manage access across a multi-contractor project is essential to protect one’s own IPR and maintain the correct separation across the design.

Above: Different sources of information can be effectively developed in parallel.
Summary

Complex engineering problems which need to be solved by many different disciplines are, by nature, iterative. Original design intent is constantly evolved through a process of change to meet the end goal. This constant change must be embraced and systems and processes need to be flexible and light enough to incorporate into daily working practice without adding complexity or overhead. The ideal of creating a design which is ‘right first time’ is unachievable and no software system can shortcut the process of design evolution.

AVEVA’s concept of the Design Spiral outlines the common design process employed around the world and the key principles that need to be in place in order to keep control of this spiral. Engineering & Design for Lean Construction supports the basic lean principles below.

- **Respect for people**
  Each discipline in the engineering design process is respected by empowering them to see each other’s information when it is at an appropriate approval level. Checks can be made to immediately see differences, to adapt to changes in the design and to be able to modify information based on other discipline changes. An integrated approach to Engineering & Design helps the team to work better together by providing controlled visibility to each other’s information, to work on a shared resource in the 3D model.

- **Eliminate wastage**
  Time spent reworking issues which have been allowed to grow into significant errors is massively reduced by sharing information immediately changes are made. Shared catalogues avoid time wasted repeating the creation of reference data; centralised management of the catalogue is key to efficiency.

- **Maximise efficiency on value-adding work**
  Common tools, a common language and controlled visibility of multi-discipline data are vital to continual improvement in the efficiency of design and engineering practises.

AVEVA understands the need to support the complex nature of the design environment, and provides unique technologies to keep all design stakeholders aligned in their understanding of the state of the design model.

For information about how AVEVA can provide solutions for integrated Engineering & Design and can help your organisation to fulfil the promise of Engineering & Design for Lean Construction, go to [www.aveva.com/futureofplantdesign](http://www.aveva.com/futureofplantdesign)

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References


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