Application of theoretical engineering concepts in a modern engineering environment

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Every process engineer acknowledges that process simulators and 3D design solutions are irreplaceable tools. For many years process simulators and 3D design solutions have found widespread adoption within operating companies in oil & gas, refining and chemical industries, as well as the engineering companies and equipment manufacturers that service these industries. The legacy tools available in the market today have incrementally improved over the years to provide more features and functionality. However, they trace their origins to dated architectures, operating systems and aftermarket user interfaces, which create inherent different limitations.

The next generation of workers expects modern, scalable and easy to use solutions with technology they now take for granted – high speed internet access, mobile devices, touch screens and virtual reality. New concepts like the Industrial Internet of Things (IIoT), Industry 4.0, and Artificial Intelligence have created greater opportunities for a new proposition that provides a "Digital Twin" that cannot be provided with legacy tools.
A new generation of workers is entering the workforce that has grown up with the Internet. Millennials expect enhanced user experience to achieve faster FEED stage, increased engineering efficiency and reduction in project schedule. They will not accept user interfaces that hold them up or prevent a mobile lifestyle. New entrants will need guidance to check results for plausibility.

Providing a single source of trusted, standardized data, improving access and collaboration between engineering teams, the Unified Engineering methodology is one option enabled by the latest technologies and tools available. Directly feeding your simulations, through an Engineering solution into the 3D models will offer class leading productivity and capability to accelerate the journey and equip the teams with the tools required to support the multi-discipline project execution. Drawings, steady-state and dynamic process simulations, line lists, datasheets, P&IDs, 3D models, and isometrics, among others, are regularly updated with the data available in the Unified Engineering source of information. Students, the future engineers, become more efficient and work with reliable information as documents and models are updated in a controlled way as soon as any change is made.

The educational model transforming the theoretical classrooms setting into a hands-on practical approach, can enhance the educational environment and open the research field in academia. Introducing Unified Engineering in an active learning environment can close the gap between the educational theory and the educational practice, using a proven solution in the industry. Unified Engineering will promote students' interest in the practical subject, allowing them to experience a real engineering environment and enrich their education experience.

Key words: academia, digital twin, engineering, simulation, next generation

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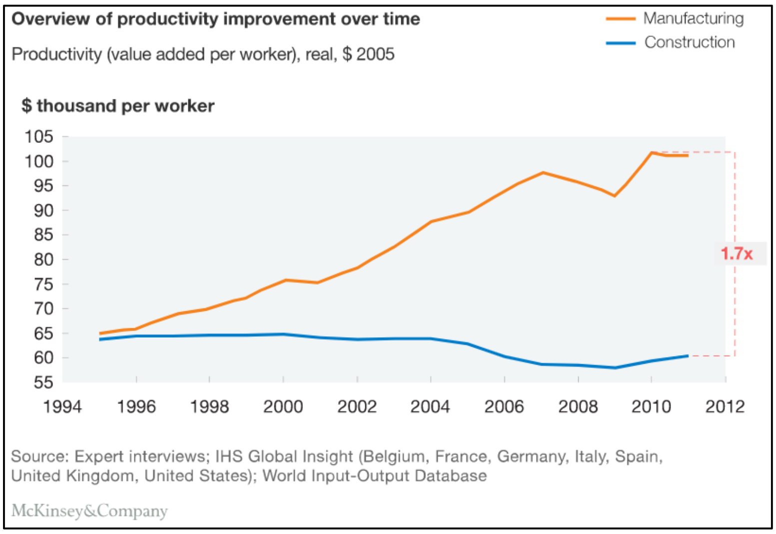
1. Introduction

Today the major trends in the Chemical Industry are related to sustainability, digitalization and innovation. There is the need of new raw material, energy recovery, circular economy, capturing data to focus on lower costs and reduction of downtime, continuous improved efficiency, attract and train the next generation of operators.
In the context of addressing those trends, companies are looking at how they can digitally transform themselves. Digital transformation is not only looking at using digital solutions and digitalization of information to replace manual activities or work processes, but it is also taking into consideration how to adapt the work processes to be best suited and most effective when applying the new digital solutions as part of day to day activities and how the end user consumes and interacts with this information.
We observe a rapid increase in the amount of data that is being created and generated during both the project execution phase and the operations phase. This means we need more efficient ways to provide all this information in a meaningful way to the consumer. And the increasing amount of information from both the Engineering lifecycle and the Operations lifecycle needs to be managed in a structured and logical way.
This is typically what we refer to as the Digital Twin, taking an end-to-end lifecycle view that integrates the Design & Build (CAPEX) side with Operate & Maintain (OPEX) side.
Looking more specifically at Simulation and Design, the next generation of process simulators rises as a solution with potential to address many of the mentioned objectives. The first versions of commercial process simulators were launched in the 1970´s. Since then process simulators became essential for the design and operations of process plants. Until a few years ago, all commercial process simulators were single purpose architecture, old programming code with improved graphical interface, which the extension of functionalities required very specialized skills and resources and were very time consuming.
Looking at 3D Design solutions, the shift to more modern technologies has generally been made about ten years ago, providing a single environment for multi-disciplinary teams, within the business and/or including partners, to contribute to a single 3D model, eliminating errors and rework to feed accurate data into procurement and material management solutions to ensure most accurate supply chain and construction management activities.
Combining Simulation and Design solutions, which has not been done before, makes it now possible to improve the Front-End Engineering Design (FEED) phase of the project significantly.
Today´s technologies allow suppliers to provide better solutions to those markets that are in constant change. With the next generation of engineering solutions, it is possible to build the Digital Twin to support the entire lifecycle of the plant. Digital Twin technologies, initially adopted by the automotive and aerospace industries, are now promoting big changes in how plants are operated and managed. With the improved visibility, availability and efficiency these new technologies provide a better environment for decision-making.

2. Industry 4.0

While the cost of engineering and design typically amounts to just 10% of the overall project cost, the work being carried out here heavily influences what happens in procurement and construction, which typically amounts to 80% of the overall project cost and is the phase where an Engineering Procurement Construction (EPC) organization generates or loses its operating margin.
The leading cause of rework in construction is design errors and omissions, and according to research, they contribute to over 5.4% of the total construction cost[1]. Engineering errors alone make up 14.2% of the Total Installed Cost (TIC)[2]. Reducing engineering and design errors is therefore an essential factor in lowering project cost and minimizing risk of overruns and delays. Action must be taken within the engineering phase to ensure these figures are minimized, and to lower TIC.



The figure above shows that the productivity per worker in the Manufacturing industry has nearly doubled in 20 years compared to the Construction industry that has almost remained flat. While the Construction industry was probably one of the first industries to adopt digital technologies in the 1970's it has not adopted next generation technologies as fast as other industries have taken these onboard. In fact, only the Agriculture industry has generated less added value over the same period[3].

Another McKinsey&Company report identifies significant increases in construction cost overruns. Large projects across asset classes typically take 20 percent longer to finish than scheduled and are up to 80 percent over budget[4]. One of the most important reasons for this are the paper-based approach processes. Digitizing these processes leads to more predictable and repeatable outcomes.

	Maturity and Accuracy Scores		
Performance	**High Maturity High Accuracy** M>80, A>76	**High Maturity Low Accuracy** M>80, A<76	**Low Maturity Low Accuracy** M<80, A<76
Cost (N=32)	2% below budget (N=11)	6% above budget (N=9)	22% above budget (N=12)
Change Orders (N=31)	4% of budget (N=12)	9% of budget (N=8)	16% of budget (N=11)

(N = Sample of Completed Projects)

If we take a closer look at the FEED stage of a project, we identify that a more mature and accurate FEED in the early stages of industrial projects improves cost and change performance, while helping meet financial performance and customer satisfaction expectations. 80 percent of project costs are locked in during Front End Engineering. Therefore, getting better control in the early stages can significantly improve the project performance and keep the costs below budget as showed in the figure above[5].

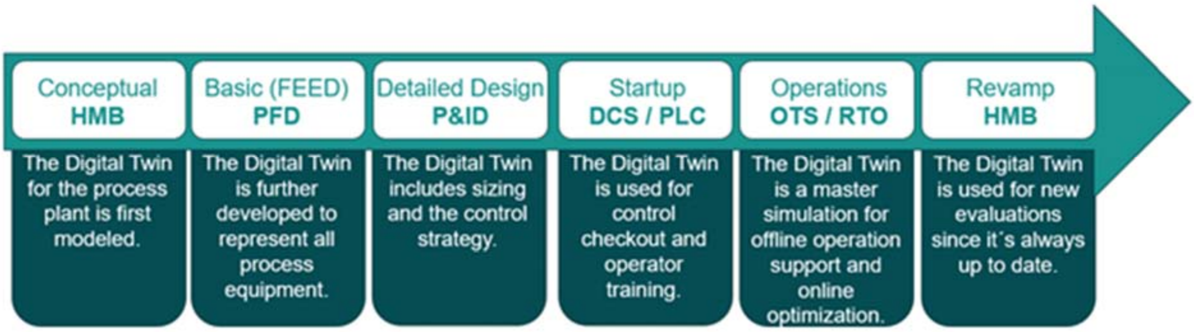
3. Digital Twin

The inception of the Digital Twin begins with Engineering, which takes it through the stages of design, procurement, and construction through to commissioning and handover to Operations. At this point, the "Design Twin" transitions to the "Operations Twin" where the processes are staffed and trained, operations continuously improved and optimized. All throughout, costs are diligently accounted for including the maintenance as well as the ongoing modifications of the assets.
Ultimately, digital twins accelerate Digital Transformation by:

- Creating value through data and maximizing the opportunities to impact both CAPEX and OPEX via a lifecycle approach.
- Revealing inefficiencies or the "value leaks" throughout the entire "money machine".
- Providing innovative insights to design not only smarter assets and processes, but also think about how to design competitive advantage into the business model itself from the outset.

A significant step was taken only a few years ago in terms of process simulation, enabling the Digital Twin built over a simulation platform that supports the entire plant lifecycle.
In the conventional approach, a static process simulation is built during the conceptual engineering phase. Then during the detailed engineering phase, several simulations are built using different tools for different purposes. These other tools must be adopted since the design phase requires equipment sizing and utilities systems need to be sized as well (cooling water network, steam balance, flare relief network and others). Furthermore, as dynamic simulation is traditionally very time consuming, engineering companies rarely take the time to validate equipment sizing under transient conditions, deferring trouble shooting of plant operation to the actual start-up itself, where schedule delays will be inevitable. During the commissioning phase, a new model is built using a dynamic simulation tool for control checkout and operator training (OTS), which requires additional engineering labor and software licenses access. After plant start-up, usually a new static process simulation is built to perform offline studies and to support operation, since the previous simulation used during the project does not comply anymore with the current operating conditions. At the same time, during the operating phase, many plants will have one more process simulation for a different application: Real Time Optimization (RTO), an online application for data reconciliation and optimization, considering economical aspects of the market and plant constraints. Very quickly this text mentions six different simulations of the same plant, which results in considerable engineering hours to convert and/or re-build simulations, different software licenses and, the worst of all, data inconsistency across the lifecycle, introducing a high risk of mistakes.
The new generation of process simulation uses a platform approach that evolves the simulation model from the conceptual engineering to the operation optimization. It allows the use of the process simulation Digital Twin, expanding benefits to the entire plant lifecycle. The same platform is used for process simulation and process utilities (cooling water, flare, steam and others), allowing engineers to further evaluate how each system impacts the other. Heat and material balances can be re-evaluated after equipment and pipeline sizing, with little or no extra engineering effort. Once sizing is validated, the simulation is switched to dynamic mode, in which control loops are included to the simulation model to validate the process control

strategy. As it is easier to shift the simulation to dynamic mode, dynamic studies are performed earlier in the project lifecycle. This promotes savings in equipment acquisition and in operating costs, since control logic responses are evaluated in earlier stages. Plus, when something doesn´t respond as expected, simulation is taken back to steady state mode, for re-evaluation of heat and material balance and re-sizing. **The ability to go back and forth between steady state and dynamic** modes is critical to increase efficiency in the project lifecycle, leading to huge savings in engineering effort.



The Digital Twin role through the plant lifecycle

The Digital Twin for process simulation can address several issues identified under the 3 mega trends presented by Market Research Blog for the Chemical industry, as follows:

- **Sustainability & the Circular Economy:** The Digital Twin allows chemical companies to simulate the entire chain identifying bottlenecks and exploring design optimization. As it´s a modern technology, the friendly interface allows engineers to easily evaluate new raw materials, different sources of energy and heat integration, focusing on maximize renewables and comply with environment regulations. Plus, as the same simulation supports the entire lifecycle, it is possible to manage knowledge, increasing re-use and reliability of new solutions.
- **Digitalization:** Integration of the process simulation with other data platforms is crucial for chemical companies to fully embrace digitalization. The Digital Twin shall be integrated with historian data to use real time data as input, allowing engineers to get faster answers from different situations. Also, the integration with the Engineering & Design solutions boosts digitalization keeping all data and documentation (flowsheets, equipment datasheets, etc.) with consistent and reliable information.
- **Innovation & Accelerated Globalization:** The need for consistent growth demands the use of innovative technology. The Digital Twin ability to evaluate process design and control strategies within the same simulation model enables the balance between capital cost and operability. At the same time cost optimization can be calculated while evaluating plant expansion, new raw materials and new operating conditions. Highly complex and integrated process, such as cumene production process, can easily be designed and optimized.

4. Unified Digital Engineering

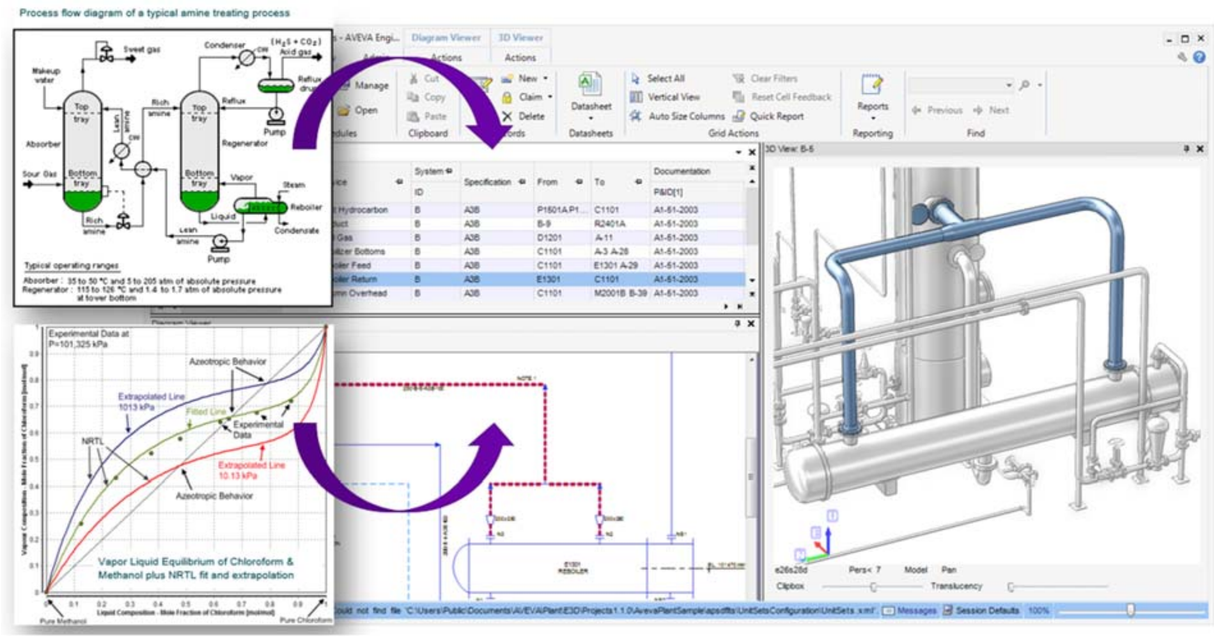
New technology enables the workflow transition from a document-centric to a data-centric approach. The data-centric approach focuses on keeping the data correct and then updating the documents and

applications. Using the data-centric approach is the basic requirement to evolve to a Unified Digital Engineering workflow, allowing EPCs to develop the plant Digital Twin.
This goes beyond the integrated engineering platforms adopted by some EPCs because Unified Digital Engineering uses a truly single source of data for all the disciplines. All process simulation, line lists, flowsheets, datasheets, 3D models, isometrics, etc. are all managed and updated within the same platform, configuring your real-time Digital Twin. Engineers can work concurrently from this single database where all documents and models are automatically updated in a maturity controlled way as soon as any changes are made. Engineers don't have to raise the question whether data is correct or not. They can trust the information they are handling.

Unified Digital Engineering enables global multi-discipline teams to work concurrently in a common data-centric environment, controlling and managing change across the entire project. This breaks down the silos between FEED and Detailed Design. The simulation data created in FEED is readily available for use in Detailed Design and is checked and validated in real-time, increasing efficiency, minimizing risk, and maximizing return on investment on your Capital Projects.

Once you have the tools in place, the true value of Unified Digital Engineering is realized because of how effectively your teams can now collaborate together. Projects are started faster, process behavior is optimized, and time is saved – time that can be invested in new innovation for your business. By adopting Unified Digital Engineering, costs are reduced across the project lifecycle, especially from commissioning and start-up and into operations. With the improved profit margins, you can ensure your business is in a stronger position than ever to compete for, and win, new projects and new contracts.

The illustration below highlights the principles of an integrated process simulation solution with the engineering and design solution for seamless and improved project execution and reduce cost and time to final delivery.



Unified Digital Engineering can save up to 30% of engineering efforts during the Engineering phase and enable further benefits in future phases of the project to ensure lower Total Installed Cost (TIC).

5. Conclusion

The industry is rapidly and increasingly adopting Digital Transformation and see the benefits of creating a Digital Twin to both manage their project execution and operations. The initial fear of change of not only adopting digital solutions, but also adapting to more digitalized processes has rapidly made way to the significant advantages that can be taken from making everything digital. Not only thinking of current efficiency gains that can be made, but also looking into the future and being better prepared for attracting the new workforce. Being able to make better use of the increasing amount of data, exploit it with new analytics capabilities and provide it to the new connected worker in the right context to get better design, perform faster troubleshooting, reduce downtime and, finally, promote collaboration and innovation.

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