C. RENTSCHLER, Engineering Consultant, Akron, Pennsylvania
and G. SHAHANI, Shureline Construction Inc., Kenton, Delaware

Construction—The cornerstone of a successful project

Construction is essentially a cyclical business. This trend is true for residential, commercial and industrial construction. Within the industrial sector, the chemicals commodity industry is highly cyclical, alternating from periods of boom to bust. This inherent cyclicality has been exacerbated by the extreme volatility of oil and gas prices. A recent industry report presented an interesting correlation between the price of oil and capital expenditures (CAPEX) in the chemical industry (FIG. 1).[1]

In addition to oil prices, several factors affect CAPEX, such as economic activity, interest rates, growth rates, overseas competition, political climate and one-time events such as Hurricane Harvey, which caused extensive damage along the US Gulf Coast—home to nearly 50% of US refining and chemical capacity. In July 2017, the American Chemical Council estimated a total of 310 projects representing $185 B in new capital investment in the US chemical industry. A significant portion (approximately 40%) of this expenditure is related to construction. This level of expenditure requires a thorough understanding of best construction practices and risk identification.

Business trends affect construction. A major challenge of the construction industry is that it fluctuates based on the state of the industries served and the geographic location of the planned project. Since most companies specialize in specific industries and are focused in specific regions, these aspects make it extremely difficult for construction companies. For example, oil and gas projects are in short supply because of low oil prices. This industry shows signs of rebounding, but the lull has created a problem for construction companies serving this industry.

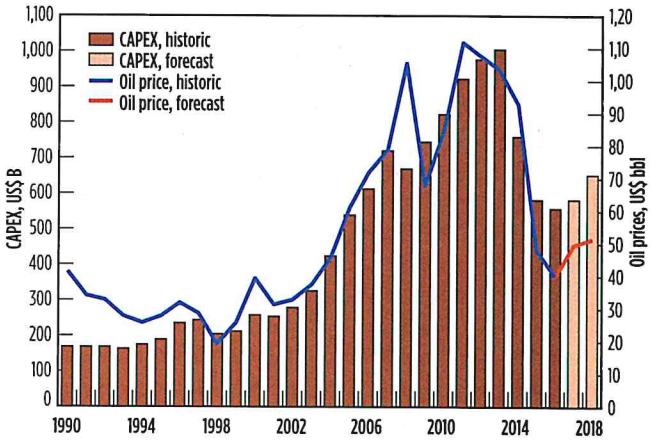
Another complicating factor is how construction is basically a local and regional business in terms of craft labor. Even if construction activity is occurring in another geography, it is very difficult to redeploy craft labor from one region to another without incurring significant costs. The problems manifest in the ability to maintain core personnel and capabilities.

Highway and bridge projects are in large supply because of the infrastructure refurbishment overtaking the US. An abundance of projects are happening in this sector, and the future can be even brighter if the present administration proceeds with its plans for overhauling the country's infrastructure. Additionally, activity in the healthcare industry, and commercial and residential buildings depends on geography. The dilemma is that petrochemical, oil and gas contractors are not experienced in infrastructure projects, and generally cannot make what seems like an obvious switch. The same scenarios exist with contractors specializing in other industries, and the ability to "balance" workloads becomes difficult during slow times in their preferred business area(s).

Construction drives a project. The construction portion of a major project can comprise between 35% and 50% of the total project cost. For this reason, construction is a deciding factor for whether a project should proceed, and whether the project budget is adequate. The other complicating factor is that the largest portion of the project's cost is also the riskiest. Engineering and procurement have their risks, but they cannot compare with the magnitude of uncertainties that frequently characterize construction projects. Even with the best outlook for events that might impact construction costs, there are often areas that were not envisioned. These blind spots can lead to grave situations in midstream.

In the case of publicly funded projects, the project may be delayed until further funding is available. In the case of private projects, the return on investment (ROI) for downstream activities may come into question because of the outstretched capital that is invested due to construction cost overruns.

In the authors' experience, once a business opportunity presents itself (e.g., sale of gas or some other product), every effort is made to trim the capital estimate of the project so the num-



Notes: Dollar amounts have been adjusted from nominal to real for all periods. Multiple regression analyses were used to test whether oil prices significantly predicted capital spending. With CAPEX lagging oil prices by 1 yr, oil price significantly predicts CAPEX with 87.4% variance ($R2 = 0.87$, $p < 0.01$).

FIG. 1. Oil prices vs. CAPEX. Source: PwC. Source: Rystad Energy (CAPEX); US Energy information Administration (oil prices).

bers work and desired profit margins are achievable. Inevitably, the first estimates presented by the project estimating team are woefully high, and the business people push for lower numbers. Engineering tends to be a relatively low percentage of the project cost (e.g., 10%–15%); therefore, it has little effect on the total cost. Procurement can be a significant cost, but this is an area that is easily quantifiable, so there is often little flexibility in this area.

Conversely, construction is characterized by variability, and is an area that is often relied upon to lower project estimates. Unfortunately, construction costs are often challenging to define and compounded with extraordinary risks. For these reasons, it is a dangerous proposition to lower construction estimates based on a positive, early outlook.

One way to define construction costs is to undertake a detailed labor survey for a given geography. This survey entails a detailed discussion with an experienced and reputable local contractor. The discussion must be quantitative in nature. It should cover the availability, unit cost and productivity of labor. Furthermore, a serious attempt must be made to forecast the future when construction will actually be carried out. It is important to be realistic with construction estimates and risk evaluations, and stick with the outcome. Based on project failures witnessed by the authors, the best outcome in some cases may be that the project does not move ahead.

In many ways, a small project (less than $10 MM) is more challenging than a large project (more than $100 MM). Small-scale projects have a lower margin for error, and the schedule tends to be shorter. To avoid surprises, it is important to define the project scope. This means carrying out sufficient engineering upfront to identify as many risk factors as possible. However, small projects usually do not have the funding to conduct thorough front-end engineering. Given the competitive nature of the marketplace, it is not possible to carry sufficient reserve and contingency to cover unknowns.

Risk avoidance is the goal of all parties involved in a project. This is particularly true with the construction portion of the project.[2] The owner or business leader wants a project that is delivered on time and on schedule so that the business plan's product margins are achieved. The team executing the project—whether an engineering, procurement and construction (EPC) company or some other arrangement—wants a trouble-free project that leads to a reasonable profit for the organization. Likewise, the contractor is looking for a profitable project that enhances the reputation of their company. Risk avoidance comes with a price, and this is the essence of the contract arrangement that is discussed during the early stages of a project. Unfortunately, project parties are often too optimistic about how construction will work out, which can lead to financial problems for one or more parties involved in a project. A realistic assessment of all possible construction risks is crucial during the estimate stage, particularly if the numbers are concerning. With this data, judgments can be made with eyes wide open, even if this means that a project is not undertaken, or is undertaken in a different form.

State of construction. In recent years, the construction industry has faced significant challenges with budget and schedule performance. According to industry research, only 30% of firms deliver projects on budget, and only 15% deliver on time.[3] All parties are looking to minimize risk, and this has led to construction firms accepting some difficult contract terms.

The business climate is contributing to the difficult situation within the construction industry. Owners and project developers seeking construction services have been taking advantage of a buyer's market that often allows them to dictate contract terms. The supply-and-demand scenario forces a competitive pricing situation, as well. This business climate contributes to overruns, as glitches are encountered during the construction process. An added complexity is that projects are becoming more demanding and complicated in design. Not only are budgets being squeezed, but more unknowns are also being added.

In the past, construction projects have had a greater chance of success for a variety of reasons, which can be broadly classified as end customer, employee and project development work process.

End customer (owner). Previously, large chemical and refining companies had competent engineering and construction departments. Work was completed in-house, under complete control. The communication between engineering and construction departments was seamless, and objectives and priorities were completely aligned.

At present, most engineering and construction activities are outsourced. Although we have the benefit of advanced communication tools (e.g., cell phones, computers, etc.), personnel are dispersed across different entities and time zones. Furthermore, employees are not always aligned with respect to the project goals. In many cases, engineering and construction firms want to make money in their narrow silo while not always doing what is best for the owner.

Employee. Often, employees do not have sufficient experience, skills or knowledge to be effective in a complex and changing project environment. Occasionally, employees do not have the proper training. In addition, generational differences in terms of work–life balance exist. Furthermore, due to many rounds of layoffs over the past decades, there is less long-term loyalty to any organization.

Project development work process. Tremendous schedule pressure is placed on projects. Final approval takes a long time, with many internal gated reviews. As a result, proper planning and sequencing is not thoroughly performed. Engineering is not fully completed before field construction begins. Equipment often arrives in the field too early or too late. Project reserves are minimal to achieve cost targets, so money is unavailable for accelerating the schedule or for unexpected changes.

In the past, deals were done on a handshake. Now, complex contractual arrangements and litigation are more common. It is essential that the owner and engineering and construction companies have better relationships. A sound relationship among the firms to provide various aspects of engineering and construction is equally as important, so that the end customer may benefit.

The focus on safety has paid off. Making safety a priority drives efficiency and conscientiousness. A safety incident is bad for everyone, including the owner, operator, and engineering and construction company.

The US construction industry is facing additional challenges not seen in many parts of the world. One of the main factors is a lack of skilled workers for projects. It is believed that the mismatch between the number of available construction jobs in the US and the number of skilled workers will continue as baby

boomers retire. This lack of skilled labor leads to inefficiencies that can quickly increase costs. Escalating labor costs in the US eventually cause budget problems, as well. The US faces stiff regulations that are not seen in other parts of the world. Not only are these regulations often costly, but they are also constantly being changed, so it is often difficult to stay up-to-date with requirements.

Causes of the rise in overruns and related problems. The following reasons contribute to construction woes:

- **Low productivity.** It has been well documented that construction has lagged in productivity improvements over the years. Fredric Plotnick stated in a recent article that, "Since 1995, the global average value added per hour has grown at about a quarter of the rate of manufacturing."[4] He explained that no other industry has performed as poorly. This statistic points to a staggering problem with progress in a critical area.
- **Shortage of qualified workers.** Although the construction industry may not be booming as it has in recent years, insufficient skilled labor is seen in many other trades. The younger generation has been pushed toward college and not toward vocational trades. This trend has left a serious gap in construction capabilities, and it often leads to construction inefficiencies.
- **Projects are complex.** Each project is unique, and many are complex. A high potential for unforeseen problems exists, and costs can vary according to conditions. The remoteness or small footprint of construction sites are often challenging.
- **Regulations are challenging.** Regulations, primarily in the environmental area, have been escalating since the 1970s. While no one will minimize the importance of protecting human health and the natural environment, complying with regulations is costly and time consuming. Regulations are a risk item that must be carefully addressed.
- **Contract arrangements are more complex.** All parties in a project want to minimize risks. This can lead to non-preferential contract arrangements for the contractor. This arrangement is particularly true in cases where a project is competitive, and undesirable arrangements must sometimes be accepted to win a project. In general, things go smoothly until construction uncertainties present themselves, and then cascading problems can arise when the contract prohibits extra costs.
- **Technology adoption.** A myriad of technology advances have been made in the construction industry to improve performance. However, putting these advances and initiatives in place takes time and money, and can affect long-term employees. Advances in technology include cloud-based software, drones, building information modeling (BIM) and laser scanning, among others. Once in place, these technologies will pay dividends, but accomplishing that can create issues.

- **Schedules are getting shorter.** In today's demanding business environment, it is critical to get a project up and running as soon as possible. Until a project has started, it is not generating any revenue or profits for the owner; therefore, there is a strong driver to compress the schedule. Often, this time crunch leads to beginning construction before all of the necessary engineering is complete. While it may appear to save money, the premature initiation of construction activities invariably leads to construction change orders. This result adds cost, delays startup and can cause friction within and between project teams.
- **Outsourcing and offshoring.** If done properly, these strategies can save time and money.[5] However, they add complexity to the project in terms of coordinating and communicating with multiple entities, which are often located in different regions of the world.

What can be done? Additional literature discusses various type of contracts (E, EP, EPC) for successful project development and execution, including lump sum, reimbursable, alliance, hybrid and unit price.[6] The choice depends on the nature and location of the project, as well as the skills, resources and tolerance of each party. No single right answer exists, and every project must be carefully evaluated.

Early planning is key to ensuring success during the construction phase, as well as to minimize unexpected problems during project execution. While a construction company may not be part of the project team during early planning, it is absolutely necessary that construction representatives be involved. The authors are familiar with situations where the contractor was brought on as part of the project's bidding phase. While this adds costs, it has been shown that the early construction input pays dividends as the project progresses. Some of the key issues that must be discussed include the overall construction strategy and what portions can be modularized. The ability to procure the necessary labor should also be key in early discussions. This aspect becomes particularly true in an area that is remote and does not include acceptable labor levels.

Another key point is early planning for the delivery of major equipment. For example, if rail or waterway is not an option, what roadway restrictions exist? Numerous construction points influence the project's schedule and cost, and these points should be discussed and planned for during the bidding stage. A thorough risk assessment is critical so that proper contingencies are included in the project estimate.

It may seem obvious that the internal organization of a company should tie together all elements of a project, but this does not always happen. In some situations, many of the construction execution strategies are made separately from the project team, leading to questionable results during execution. The basis of such an approach is bundling construction projects to obtain better pricing, but the details of each project are critical to determining a contract basis. The project manager and engineering team should be key to construction strategies. It is important that the project manager (or project development manager) drive the planning process and frequently involve construction experts.

It is ideal to have all engineering completed before construction, but this is generally not possible. At the very least, piping and instrumentation diagrams (P&IDs) should be certified, and a hazard and operability study (HAZOP) should be completed before construction. In some instances, piecemeal P&ID certification is used in cases where wholesale certification cannot be completed due to missing information. This technique minimizes the amount of design at risk.

Including construction personnel as part of the engineering team has also been shown to be beneficial. This setup ensures constructability, and it offers the possibility for introducing design features that facilitate easier construction. Accomplishing engineering in a timely and thorough manner is key to successful construction. It also reduces the amount of issues that represent a risk to the project.

Recently, an effort has been made to take construction out of the field through the modularization of components. This approach can add cost if not carried out properly, but it can also alleviate many of the concerns inherent with field construction.[7] Early engineering is imperative for successful modularization, along with a thorough study of shipping options.

Takeaways. Construction is a cyclical and risky activity. Challenges of this project phase have been exacerbated by the extreme volatility of oil prices in recent years. In addition, there is a tendency to be overly optimistic in terms of construction costs to get projects funded. Furthermore, projects are getting larger and more technologically complex, with shorter schedules and a lower margin for error. Project execution strategies that involve outsourcing and offshoring can sometimes add to the risk. Additionally, construction is challenging due to a lag in productivity improvements and a lack of skilled craft labor. These factors must be clearly understood and addressed to ensure a successful construction project. HP

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CARL RENTSCHLER is an engineering consultant specializing in project management, business development, client relationship management and procedure development. He has more than 40 yr of varied engineering and management experience with three international EPC companies in the power and petrochemical fields. Mr. Rentschler holds a BS degree in civil engineering from Penn State University and an MEng degree from Cornell University.

GOUTAM SHAHANI is Vice President of sales and marketing at ShureLine Construction. Previously, he was Business Development Manager at Linde Engineering in North America. With more than 30 yr of industry experience, Mr. Shahani specializes in industrial gases for the energy, refining and chemical industries. He holds BS and MS degrees in chemical engineering, as well as an MBA degree.