HP | Plant Design, Engineering, Construction and Commissioning

The importance of operational readiness

G. LADNIER, JEM Advisors, Biloxi, Mississippi; **G. MCLEOD,** GMcLeodConsulting LLC, San Rafael, California; **B. STRAKER** and **T. HANSON,** JEM Advisors, Houston, Texas; **R. KENYON,** JEM Advisors, Big Bear Lake, California; and **A. MATTSON,** Austin Mattson Project Management, Las Vegas, Nevada

Over the last 20 yr–30 yr, manufacturing facilities and project teams have spent significant time and money developing tools to navigate the issues of designing, procuring and building projects. During this time, there was often less focus on how these new projects would be received and put into service by the facility operations organization. Many project owners have struggled to recover their projected return on investments (ROIs) due to their inability to start up and run the new facilities to capacity on time (**FIG. 1**).

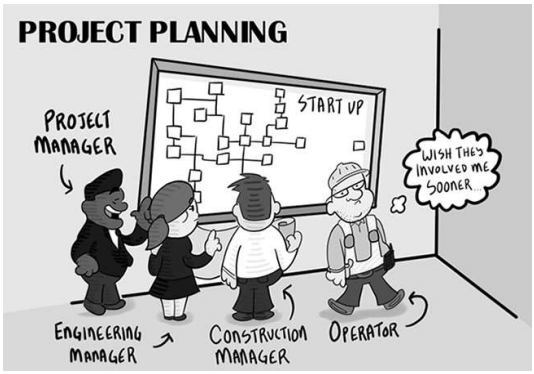

FIG. 1. A project without an OR process. Source: Created by Roman Tingle.

This has led many companies to develop processes and tools designed to ensure that operating organizations are prepared to receive the completed project, and then to safely start up and ramp up the new facilities. Many companies have begun to introduce key personnel from the operations group (including operators, maintenance, engineering and other relevant disciplines) into the project during early front-end loading (FEL) phases. Their mandate is to provide valuable input for design and equipment selection, and to prepare people, processes and procedures for commissioning, startup and facility operations. Adding key operations representatives to the project team in the early phases helps to fully analyze the trade-offs between capital expenditures (CAPEX) and long-term operating expenses (OPEX) when making decisions on design and equipment selection, as well as provide additional assurance that the project will deliver an asset that will be functional, operable, maintainable and reliable for the planned project life. A common name for these processes is operational readiness (OR).

The often-referred-to "influence vs. cost" profile is still valid to this day. **FIG. 2** provides an overview of how operations input can have a huge impact on the total lifecycle cost.

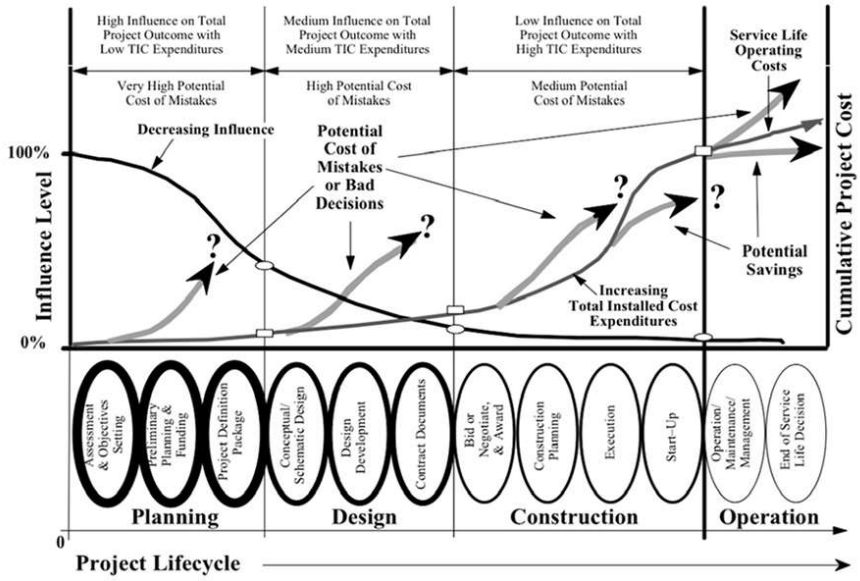

FIG. 2. Project influence vs. project cost. Image has been developed from literature.[1]

Big decisions are made early in the project phases, and these decisions can have a major bearing on CAPEX and, more importantly, on the lifecycle costs and reliability of the asset. History shows that project managers have, for the most part, been rewarded for delivering a project on schedule and within budget; however, one potential trade-off can be a lack of focus on the asset owner's objectives and the lifecycle reliability of the new asset. Repeatedly, project teams are disbanded immediately after commissioning/startup, with little accountability for ensuring that the new asset will achieve the production goals—this can result in operations being left with a facility that is not completed to the standard required to support lifecycle integrity and reliability. To deliver an operationally successful project that meets its project objectives, this must change.

The authors' organizations recognize this issue and have built an OR process to ensure that lifecycle costs are identified and considered during the early stages of the project. The purpose of this article is to:

- Provide a broad overview of the OR process
- Show key OR activities
- Demonstrate the importance of considering OR when developing engineering, procurement and construction (EPC) or EPC management (EPCm) contracts
- Show how OR can be customized for varying project scope

- Explain how OR can be measured, monitored and confirmed
- Detail why OR is important to the success of a project
- Discuss case studies regarding OR.

What is OR? OR encompasses all activities under the asset owner's responsibility regarding operation of the new or modified asset. OR ensures that all site systems, processes, organizations (maintenance, technical, reliability) and people are ready for turnover and safe operation of the facility.

OR is a process that starts in early FEL of a project and increases in effort as the project proceeds toward completion. The OR process provides for critical operational input during project development and execution, considering the needs of the site's operating organization. It ensures that all aspects of operations are prepared to receive, commission, start up and maintain the facility. The definition of operations for the purpose of OR is inclusive of all groups within the facility that directly or indirectly support plant operations. OR planning starts very early in the project lifecycle and increases in importance as the project progresses.

Some of the key attributes that the operations organization contributes to early project phases include:

- Capturing benchmarks on design, reliability and equipment and feeding those learnings into the design and equipment selection
- Creating a trade-offs matrix, where CAPEX options are weighed against lifecycle OPEX estimates
- Generating decision support papers, where all key stakeholders document, approve and sign off on key decisions
- Attending 3D model reviews with a strong bias on operability and maintainability
- Being part of the factory acceptance testing (FAT) programs, ensuring that operational needs and concerns are addressed before mobilizing equipment to the site
- Overseeing the equipment preservation program, from pre-installation through startup.

Development of the OR process should cover all aspects that may be required for a project. Each type of project can customize the process to fit the need, including the staffing and effort required for OR activities in each of the project phases. The different types of projects and how that impacts OR will be discussed later.

In providing requirements of OR, the authors group the activities into two areas:

1. **Early phase OR activities:**
    - Benchmarking and performance
    - Input to design
    - Trade-offs and decision-making
    - Planning
    - Engagement with functions
    - OR staffing integrated with the project.
2. **Execution phase OR activities:**
    - Operating phase staffing
    - Competency and training
    - Risks and mitigations
    - Health, safety, security and environment (HSSE) management system
    - Operational startup process, plans and procedures
    - Energy isolation and management of change (MoC)
    - Project information management
    - Crisis management
    - Maintenance, reliability and inspection programs
    - Operations support contracts
    - Spares management
    - Permits and regulatory approvals
    - OPEX and business plans
    - Handover and accountability
    - Engineering, construction and commissioning support.

As shown by this listing of activities, the operations team will need assistance from many, if not all, of the supporting groups within the facility to complete this effort. The OR effort should be driven by operations and supported by maintenance, engineering, HSSE, information technology (IT), procurement and other support organizations. Staffing to cover all these activities must be included in the project budgeting process to ensure complete OR at the handover point of the project. Many organizations have developed a work practice or procedure to make sure that all this planning and these activities occur at the proper time.

OR means achieving a configuration that places the right people in the right places at the right times—working with the right hardware, and with the right procedures and management controls. The project hardware must be installed and tested per project specifications to ensure that it will function properly. **FIG. 3** helps illustrate the relationship among the different readiness elements.

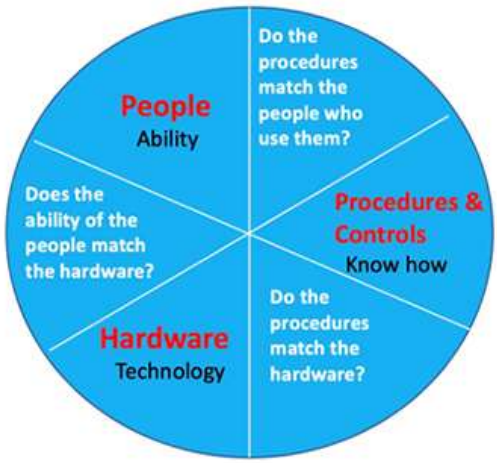

FIG. 3. The relationship among OR elements.

OR requirements must be covered within EPC or EPCm contracts. OR considerations must be included in the project contract, regardless of the contract type. This is necessary to clearly identify OR responsibilities and to avoid misalignment between the contractor and the owner's teams. Because the construction team's primary focus at the start is bulk completion, priorities are often misaligned between the construction group and the commissioning and startup groups that work at the system/subsystem level. There are many reasons for this misalignment, and a main contributing factor includes unclear or ambiguous contractual requirements, which inevitably lead to conflict and delays when projects reach the stage of systems or subsystems pre-commissioning.

Many contracts are technically complicated or full of legal speak to protect one or both parties. This is not what contracts are meant to do. Contracts are meant to clearly lay out expectations for both parties so that there is no ambiguity about what is expected of, and by, both parties. Phrases like "good industry practices" or "industry norms" should be avoided. For a project to have the best chance for success, OR requirements must be covered within the EPC or EPCm contracts for projects of all kinds, including restart/preservation efforts for long-idle facilities. OR is one of the building blocks of a successful project foundation, and, thus, must be clearly defined and agreed to by all relevant parties in the very early stages of a project. Critical project milestones (e.g., mechanical completion, pre-commissioning, ready for commissioning, ready for startup) must be clearly defined and agreed upon in the contract by the contractor and owner's teams well in advance of starting the project work. Requirements and timing for shifting construction focus to systems-based completions should also be included.

Readily available industry data shows that 75%–80% of projects fail to meet operational objectives in the first year of operations. The metric "meeting operational objectives" must be carefully balanced with schedule and cost metrics when measuring the success of projects. Project objectives must go beyond simply project delivery—they should expand to include an operationally effective project delivery. Unfortunately, cost and schedule usually grab the main headlines when past successes are discussed among the project community. Schedule and cost successes are also main selling points for EPC companies.

There are many reasons for common failures in meeting operational objectives. By far, the biggest contributing factors are failures during commissioning, or, to put it another way, failing to achieve OR before commissioning commenced. OR does not just occur naturally—it is not the default result of good engineering, construction and quality control. It is something that must be planned, designed and staffed to be successful. Having the best contractors with the best engineering designs is not enough to ensure success. The facility must also be ready for safe and reliable operations.

The only way to accomplish this is to have a robust OR program in place with roots planted in early phases of the project. The longer OR planning is delayed, the more the potential for OR success decreases. Just

of the project. The longer OR planning is delayed, the more the potential for OR success decreases. Just like project schedules, OR must begin with the end in mind. The questions surrounding what it will take to ensure a safe and reliable facility must be asked. Too often, project teams develop schedules with a hard limit on the end date, or a maximum spending limit, and then they try to force OR to "fit in the cracks." This approach is fraught with risk and is a very large contributing factor in the high project failure rate previously mentioned. The contract must unambiguously state the requirement of an OR program.

How do we ensure that OR is a focus area when the contract is being written? The best approach is for an experienced project operations team to be involved in early negotiations with the contractor. The operations team must be embedded within the project management team so that the facility is designed with a primary focus on operational safety and reliability.

To summarize, project contracts must be clear concerning the requirements and expectations for pre-commissioning, commissioning and startup, which are all integral parts of an OR program. The contract must clearly identify who is responsible for each activity and how the transition from one milestone to the next will be accomplished. The verification and validation of these milestones and handover documentation are critical to the project's ultimate success. Successful commissioning and startup, verified by a robust OR program, require that the appropriate focus be on resource, budget and project schedule allocation to ensure overall project success.

Types of projects requiring OR. The following are projects that require OR:

- **Brownfield:** A revamp to existing facilities with little to no new plants. Depending on the scope of work, this project may be the least intense OR process, although a review of all required activities must be reviewed by the project owners to make a conscious decision on which OR activities will be required.
- **Greenfield with existing infrastructure and supporting facilities:** This is the real base case for the OR process: unless this is a very small project, all the activities will be required for a successful operational acceptance at project handover.
- **Greenfield with no existing infrastructure or other supporting facilities:** This will be the most intense OR process, as it requires a much broader view and can be labeled facility readiness instead of OR. Some additional considerations (not an exhaustive list) include:
    - Buildings (e.g., administrative, laboratory, central control room)
    - Security
    - Additional organizations [e.g., human resources; health, safety, environment and energy (HSEE); procurement; finance; contracts]
    - Catering, housing, transportation and a hospital, if in remote locations.
- **Restart after a major event or long idle period:** This case may not seem justified since the plant has previously been in operation. The authors have seen that adding an OR plan is a very good way to increase confidence in a restart after an incident. An incident always increases concerns, and a process like OR can help reduce incident risk. Again, a review and a selection of applicable activities will be required.

As mentioned, the OR basics will be required for all these projects, but the process should be flexible and customized to fit the purpose of each type of project (**FIG. 4**).

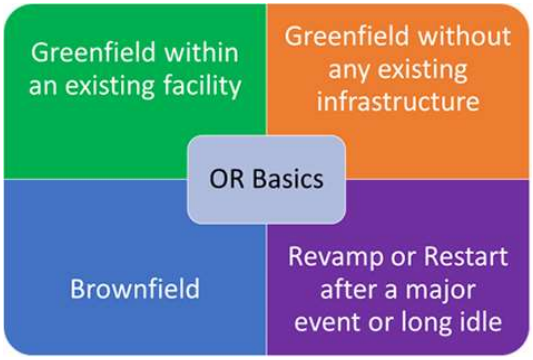

FIG. 4. Types of projects that benefit from the OR process.

Measuring and monitoring OR. Planning is paramount to a successful OR process. An OR plan should be developed in early FEL of the project and should be a live document that can be updated as the project proceeds. This plan should include OR metrics that can be used to measure and monitor OR progress. Project personnel have seen construction metrics, such as instruments installed, instruments

wired and connected, instruments loop-tested, welding inches completed, and welding inches remaining. However, how many have seen metrics for OR shown for a project?

These metrics will be most useful to communicate progress and shortfalls for OR, and they can be monitored by project and operations management for assurance that operations will be ready at handover of the project. This type of monitoring will be self-monitoring. Due to the importance of this process, it is highly recommended that a cold-eye OR review (ORR) be done at designated checkpoints within the project process. The authors believe that a cold-eye review by knowledgeable and experienced project operational subject matter experts (SMEs) will provide maximum benefits in the ORR process, as a third party can be very straightforward and honest when assessing the project. If the organization has the experience and capacity to conduct these reviews, they should be done prior to each phase gate and should include internal peers not directly associated with the project. If the organization does not have the capacity for this review, then third-party resources should be utilized for the ORR. The timing of the reviews should be tied to gate/phase changes. **TABLE 1** shows the recommended timing of ORRs.

Improvements and changes that organizations have witnessed after the development of a rigorous OR process and ORRs prior to phase-gate changes will be discussed later in the article.

TABLE 1. Recommended OR review timing

Phase 1	Phase 2	Phase 3	Phase 4	Phase 5
Concept business case	**Develop alternatives/ select best alternative**	**Front-end engineering**	**Detailed engineering, construction, pre-commissioning and commissioning**	**Startup, initial operation and performance testing**
	Early ORR prior to front-end engineering design (FEED)	ORR prior to start of detailed engineering	ORR prior to start of construction	
			ORR prior to commissioning and startup	
			For large projects, there will typically be multiple Phase 4 ORRs	

Why is OR important? Industry data confirms that 75%–80% of large and mega projects fail to meet operational objectives within the first year of operation. Exhaustive studies have concluded that these projects typically fail during commissioning. Commissioning failures are primarily due to improper pre-commissioning (cleaning and flushing) and/or handover activities (punch listing, improper documentation). **FIG. 5** provides a breakdown of commissioning delays.

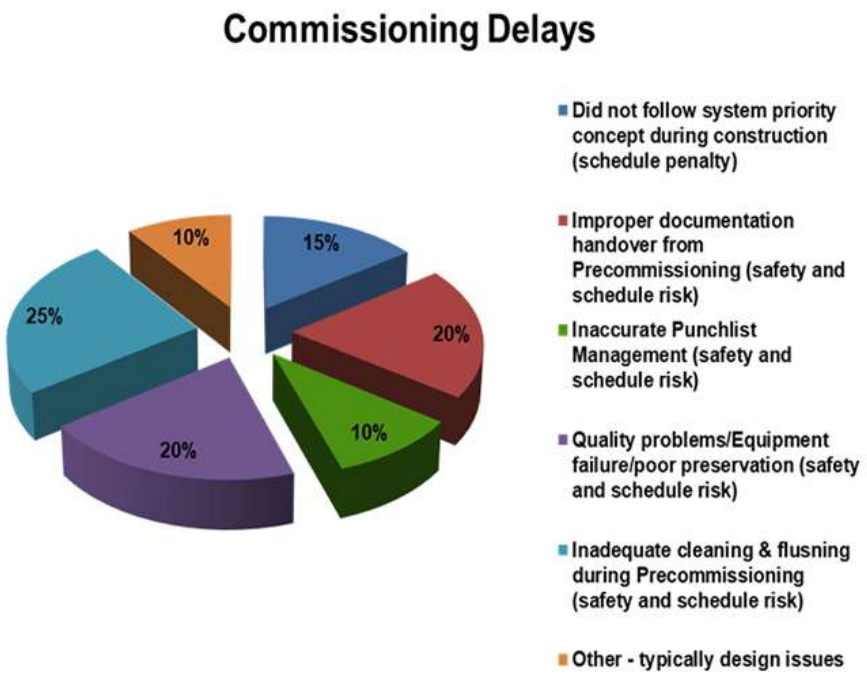

FIG. 5. Causes of commissioning delays.

Good OR planning will address these issues and many more that could impact a project's ability to safely commission, start up and reach design capacity. For brevity's sake, the following will address only two of the top reasons causing commissioning delays.

Quality problems, equipment failures and poor preservation. Quality and equipment failure issues should be managed and resolved at the project delivery level. For this article, the authors will focus on poor preservation. Poor preservation has a dual impact on projects because it incurs repair costs, and the late discovery of the issue will cause delays in the schedule. Preservation is not easily addressed; however, with good planning, proper attention, proper resourcing and management monitoring, preservation programs can be very successful. The authors have three main recommendations to ensure that poor preservation does not impact the project:

1. **Do not leave equipment preservation totally up to the EPC contractor.** It may be good to contractually require ultimate responsibility for preservation with the EPC contractor, while ensuring that an integrated EPC/owner team is established for the assurance of proper preservation. The owner's team has a personal stake in the success of this effort and must be actively engaged. Proper planning is required to ensure that an owner's team is sufficiently budgeted and staffed as required for proper oversight. This staffing adds value to the preservation effort and exposes the owner's personnel to training opportunities on the new equipment.
2. **Ensure that the completion management system has a preservation module.** When selecting which tool to track mechanical completion, pre-commissioning and commissioning check sheets/progress that the project will use, the OR program's ability to assist in preservation should be a key factor. The program should be able to print out preservation check sheets (per the manufacturer's requirements), track preservation task completion and develop reports for all preservation activities.
3. **Measure and monitor preservation.** Preservation management and reporting tools are required. The project delivery team and operations team should discuss metrics around preservation on a weekly basis. Both teams should address issues, ensure that staffing is adequate and confirm that the program is functioning properly.

Inadequate cleaning and flushing during pre-commissioning. Inadequate cleaning can affect both utility and process units. Steam systems, cooling water systems and other utility systems require a significant level of cleanliness. Lubrication systems require cleaning to the rotating equipment manufacturers' specifications. Most process units demand high levels of cleanliness, and in some cases, like an oxygen service, these requirements can be critical. Many projects have started up, only to shut back down multiple times to redo inadequate cleaning. The authors have three recommendations to assist in proper cleaning and flushing:

1. **The development of a cleaning matrix:** As part of the pre-commissioning scope, a detailed line list should be developed in a spreadsheet. Each line should be assigned (at a minimum):
    - A system number and system—Sequential numbers assigned by the project
    - Commodity type—Also assigned by the project
    - Cleaning method—List of potential cleaning methods that can include low-velocity flush, manual clean, air blow, air decompression blow, high-speed water circulation, pulse air blow, pulse water flush, aqua laze (high-pressure water scale removal), steam blow, target steam blow and chemical clean, among others
    - Cleanliness specification—At a minimum, include 1–3 levels of cleanliness, and possibly as many as 6–7 levels (these should be developed specifically by the project engineers, based on criticality of cleanliness to the utility and process units)
    - Drying method—May require drain only, drain with air blow, dry with swab pig, hot air or nitrogen circulation to a specified dew point (consider the potential for freezing if water is left in systems)
    - Post-cleaning preservation—Could include isolate and leave empty, charge with normal commodity, preserve with dry air or nitrogen, and monitor.

2. **Inclusion of all pre-commissioning requirements in the EPC contract:** Pre-commissioning is often an afterthought, or it is lumped together with construction, especially in lump-sum turnkey (LSTK) contracts. Successful commissioning is only possible if construction completion has been verified during pre-commissioning. Pre-commissioning is the physical verification that each component has been installed and tested to verify performance per project design specifications. Pre-commissioning means energized testing at a component level. Moving from one phase to the next (i.e., construction to pre-commissioning, pre-commissioning to commissioning, commissioning to startup, then startup to normal operation) must be accomplished in a systematic way with various verification and validation steps completed at each phase. This requirement, along with the owner's pre-commissioning specifications or requirements, must be clearly defined in the EPC contract. Pre-commissioning requires a different skill set than construction. It requires personnel with expertise in electrical, instrumentation, flange management and chemical cleaning, among others. When it comes to pre-commissioning activities and expectations, specificity should be the focus. Even with LSTK contracts, the time and effort must be taken to ensure that expectations between the owner and the contractor about how pre-commissioning will be accomplished, monitored, verified and validated are accomplished. This must be clearly stipulated in the project contract and not merely mentioned—or referred to—in some vague project addendum or external file.
3. **Ensure operations involvement in pre-commissioning:** Typically, an EPC firm will be responsible for pre-commissioning, and mechanical completion will be for completed construction and any pre-

pre-commissioning, and mechanical completion will be for completed construction and any pre-commissioned system or subsystem. Integrating operations into this effort and witnessing the completion of these activities will ensure cleanliness, as well as increase the operations team's familiarity of the new unit (training). In addition, embedding operations personnel into pre-commissioning by having them write the procedures and requiring an operations signature on each completed pre-commissioning check sheet could be considered.

CASE STUDY

The following case study discusses the challenges faced in the expansion of an aromatics facility, the actions taken to resolve these challenges and the results.

Challenge. An aromatics expansion project team had a project objective to produce on-spec product at a normal rate within 6 wk–8 wk of feed introduction. The project had many risk factors to successful startup, and industry SMEs projected a 1% chance of meeting this startup objective and expected an 8-mos startup period, based on a historical database of projects.

Actions. Project operations personnel, led by one of the authors' company's advisors with support from industry SMEs, determined reasons for the protracted startup forecast. The advisor also visited a company known for its success at starting up new plants and maximizing returns. The aromatics project contained many of the items that made startups difficult, and two of these will be discussed here.

One common reason for protracted startup was the introduction of new technology. The project operations team addressed this by:

- Assigning the new technology's patent holder to manage operational procedures to ensure strict adherence to technical requirements (a change from the normal way the procedures would be developed)
- Including 2 mos of turnaround (TAR) time upon project completion to complete tie-ins
- Developing a plan to test the new technology during the TAR to verify final product purity (this testing concluded that the final product technology did not operate properly)
- As a result, during the TAR, the project team engineered and installed piping to utilize the old product purification section of the plant—it was intended to be decommissioned.

Another common reason for protracted startup was the incorrect operator response to an emergency, due to pressure to meet the schedule, even when operational upsets occur. As a result, a concept of "safe havens" was incorporated into procedures to allow operators the ability to hold a project's startup until the plant was in a safe condition if an issue/emergency occurred. Operators should be encouraged to take the time to address the issue/emergency with SMEs, and to develop a path forward regardless of what schedule is required.

Results. By engaging industry SMEs and utilizing sound OR principles, the aromatics plant managed an effective startup and obtained a normal rate with on-spec product within 7 wk of feed introduction.

Takeaways. Detailed planning has always been the standard for the delivery side of a project. With a rigid OR process, the facility's operations team can be ready to receive a well-executed project, and to turn it into a safe and functioning asset to meet project objectives (**FIG. 6**).

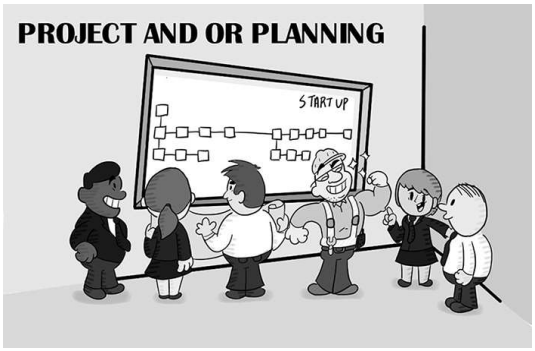

FIG. 6. A project with a strong OR process. Source: Created by Roman Tingle.

To demonstrate that OR adds value, the authors' company has developed an ORR process that includes a scorecard to quantify the OR status in Phases 2, 3 and 4 of the project. **FIG. 7** presents the scoring for one client, which captures 24 projects over the past 3 yr. There has been a defined shift in recognizing the value of OR by assessing more projects in Phases 2 and 3. Furthermore, the scores in each project phase

value of OR by assessing more projects in Phases 2 and 3. Furthermore, the scores in each project phase have generally improved over the 3-yr period. There is a higher probability that most of these projects will have a successful startup and achieve their lifecycle targets. **HP**

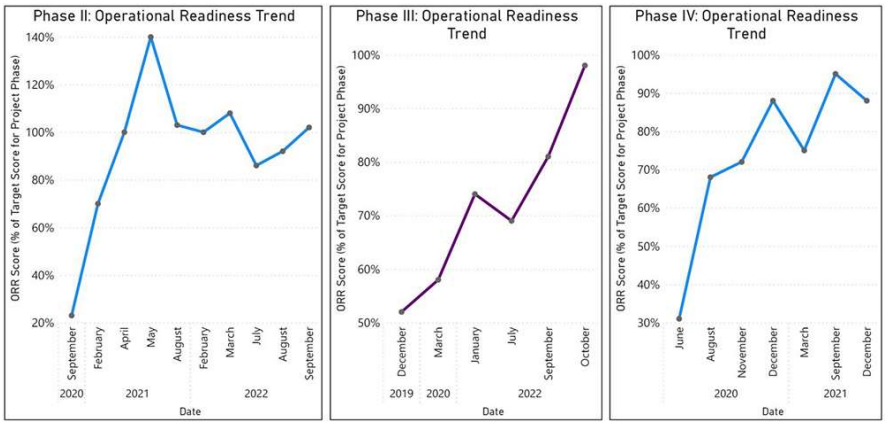

FIG. 7. A 3-yr OR process for a major petrochemical company.

LITERATURE CITED

1. Hastak, M. and A. Mirmiran, "A framework for lifecycle cost assessment of composites in construction," *Journal of Reinforced Plastics and Composites*, October 2003.

GARY LADNIER has more than 40 yr of oil and gas experience, with an emphasis on operations, systems completion and commissioning. He now works with JEM Advisors.

GAVIN MCLEOD has more than 40 yr of oil and gas experience, with an emphasis on systems completion and commissioning.

BILL STRAKER works with JEM Advisors and has more than 40 yr of oil and gas experience, with an emphasis on maintenance, reliability and OR.

TOM HANSON has more than 40 yr of oil and gas experience, with an emphasis on operations, maintenance, reliability and OR. He works with JEM Advisors and others.

REX KENYON has more than 50 yr of oil and gas experience, with an emphasis on maintenance, reliability and operations. He now works with JEM Advisors.

AUSTIN MATTSON has more than 40 yr of experience in manufacturing operations and project management leadership positions with various companies. He is now the owner of, and senior consultant at, Austin Mattson Project Management (AMPM).