



Front End Planning of Renovation and Revamp Projects

Implementation Resource 242-2

Version 1.1

CII Member Companies

Abbott	AMEC
Air Products and Chemicals	AZCO
Ameren Corporation	Aecon Group
American Transmission Company	Affiliated Construction Services
Anglo American	Alstom Power
Anheuser-Busch InBev	Audubon Engineering Company
Aramco Services Company	Baker Concrete Construction
ArcelorMittal	Barton Malow Company
Architect of the Capitol	Bechtel Group
BP America	Bentley Systems
Cargill	Bilfinger Industrial Services
Chevron	Black & Veatch
ConocoPhillips	Burns & McDonnell
Consolidated Edison Company of New York	CB&I
DTE Energy	CCC Group
The Dow Chemical Company	CDI Engineering Solutions
DuPont	CH2M HILL
Eastman Chemical Company	CSA Central
Ecopetrol	Cannon Design
Eskom Holdings SOC	Coreworx
ExxonMobil Corporation	Day & Zimmermann
General Electric Company	Dresser-Rand Company
General Motors Company	eProject Management
GlaxoSmithKline	Emerson Process Management
Global Infrastructure Partners	Faithful+Gould
Huntsman Corporation	Fluor Corporation
Intel Corporation	Gross Mechanical Contractors
International Paper	Hargrove Engineers + Constructors
Irving Oil Limited	Hilti Corporation
Kaiser Permanente	Honeywell International
Koch Industries	IHI E&C International Corporation
Eli Lilly and Company	IHS
Linde North America	International Rivers Consulting
LyondellBasell	JMJ Associates
Marathon Petroleum Corporation	JV Driver Projects
National Aeronautics & Space Administration	Jacobs
NOVA Chemicals Corporation	KBR
Occidental Petroleum Corporation	Kiewit Corporation
Ontario Power Generation	Kvaerner North American Construction
Petroleo Brasileiro S/A - Petrobras	Lauren Engineers & Constructors
Petroleos Mexicanos	Leidos Constructors
Petronas	Matrix Service Company
Phillips 66	McCarthy Building Companies
Pioneer Natural Resources	McDermott International
Praxair	Midwest Steel
The Procter & Gamble Company	Parsons
Public Service Electric & Gas Company	Pathfinder
Reliance Industries Limited (RIL)	POWER Engineers
SABIC - Saudi Basic Industries Corporation	Project Talent Acquisition Group Inc.
Sasol Technology	Quality Execution
Shell Global Solutions US	Richard Industrial Group
Smithsonian Institution	The Robins & Morton Group
Southern Company	S&B Engineers and Constructors
Statoil ASA	SBM Offshore
SunCoke Energy	SNC-Lavalin
Tennessee Valley Authority	Skanska USA
TransCanada Corporation	Technip
U.S. Army Corps of Engineers	Tenova
U.S. Department of Commerce/NIST/ Engineering Laboratory	TOYO-SETAL Engenharia
U.S. Department of Defense/ Tricare Management Activity	URS Corporation
U.S. Department of Energy	Victaulic
U.S. Department of Health & Human Services	WESCO International, Inc.
U.S. Department of State	Walbridge
U.S. Department of Veterans Affairs	Wanzek Construction
U.S. General Services Administration	The Weitz Company
Vale	Wilhelm Construction
The Williams Companies	Willbros United States Holdings
	Wood Group Mustang
	WorleyParsons
	Yates Construction
	Zachry Holdings
	Zurich



Documents

Document Sharing Hub

Front End Planning of Renovation and Revamp Projects

*Prepared by the
Front End Planning for Renovation/Revamp Research Team*

Implementation Resource 242-2

Version 1.1

October 2014

© 2014 Construction Industry Institute™.

The University of Texas at Austin.

CII members may reproduce and distribute this work internally in any medium at no cost to internal recipients. CII members are permitted to revise and adapt this work for the internal use, provided an informational copy is furnished to CII.

This work is available to non-members by purchase; however, no copies may be made or distributed, and no modifications may be made, without prior written permission from CII. *Contact CII at <http://construction-institute.org/catalog.htm> to purchase copies.* Volume discounts may be available.

All CII members, current students, and faculty at a college or university are eligible to purchase CII products at member prices. Faculty and students at a college or university may reproduce and distribute this work without modification for educational use.

Printed in the United States of America.

Version 1.0 (February 2009)

Version 1.1 (September 2014) – Corrected minor errors in STAR Tool software. Made minor edits throughout book.

Contents

<i>Chapter</i>	<i>Page</i>
1. Introduction	1
1.1. Organization of This Book	1
1.2. What Are Renovation and Revamp Projects?	1
1.3. Why Are R&R Projects Unique?	3
1.4. Shutdown/Turnaround/Outage Projects	4
1.5. Front End Planning	4
2. R&R Project Risks and Critical Success Factors	7
2.1. Increased Risk Areas for R&R Projects	7
2.2. Critical Success Factors	9
2.2.1. Ensure Alignment and Conduct Teambuilding	9
2.2.2. Choose Contracting Strategy for Project Constraints	10
2.2.3. Define Existing Conditions	11
2.2.4. Identify and Engage Key Stakeholders	12
2.2.5. Follow a Defined Front End Planning Process	12
2.2.6. Define Critical Scope Issues	13
2.2.7. Ensure labor and material availability	15
2.2.8. Explore alternative construction methods	15
2.2.9. Apply Leadership and Experience	16
3. Shutdown/Turnaround/Outage Critical Issues	17
3.1. Introduction	17
3.2. STO Critical Issues	17
3.3. STO Risk Mitigation Strategies	21
4. Shutdown Turnaround Alignment Review (STAR) Tool	23
4.1. Background	23
4.2. STAR Tool Timeline	24
4.3. Critical STO Areas	24
4.4. Example Assessment Using the Tool	25
4.5. Advanced STAR Tool Functionality	30
5. Project Condition Investigation Tools	31
5.1. What Project Conditions to Assess	31
5.2. Project Condition Investigation (PCI) Cards	32
5.3. Transit Map	33
6. Summary	35

Appendices	37
Appendix A: Unique R&R Risk Issues	37
Appendix A-1: Unique Industrial R&R Risk Issues	38
Appendix A-2: Unique Building R&R Risk Issues	43
Appendix B: Shutdown/Turnaround Alignment Review or “STAR” Tool	49
Appendix C: Sample of a Completed “STAR” Tool	67
Appendix D: Project Condition Investigation Tools and PCI Cards	85
PCI Card 1: Ground Penetrating Radar	87
PCI Card 2: Electromagnetic Conductivity	88
PCI Card 3: Hydro-Excavation	89
PCI Card 4: 3D Laser Scanning	90
PCI Card 5: Photogrammetry	91
PCI Card 6: Rapid Prototyping	92
PCI Card 7: 3D Wind Tunnel Modeling	93
PCI Card 8: Ultrasonic Testing	94
PCI Card 9: Hydrostatic Isolation Technologies	95
PCI Card 10: Infrared Scanning (IR)	96
PCI Card 11: Real-Time GPS Monitoring System	97
PCI Card 12: X-Ray Fluorescence	98
PCI Card 13: Fiber Optic Sensors	99
PCI Card 14: Acoustic Structural Monitoring	100
PCI Card 15: Smart Pigs/Smart Ball	101
PCI Card 16: Magnetic Particle Inspection (MPI)	102
PCI Card 17: Eddy Current Testing	103
PCI Card 18: Liquid Penetrant Inspection (LPI)	104
PCI Card 19: Flux Leakage	105
PCI Card 20: Falling Weight Deflectometer	106
PCI Card 21: Mass Spectrometers	107
PCI Card 22: Cost and Schedule Risk Analysis	108
PCI Card 23: Conceptual Cost Estimating	109
PCI Card 24: SCAPS	110
References	111

1

Introduction

1.1 Organization of This Book

Managing a project can be challenging during the best of times. This challenge is increased when modifying or renovating an existing facility. This implementation resource, which is based on extensive CII research, is intended to assist project teams that are working on renovation and revamp projects (or “R&R” projects), to achieve better project outcomes.

Chapter 1 introduces the definition of renovation and revamp (R&R) projects, and describes why such projects are unique. It also introduces the tenets of a special type of R&R project—the shutdown/turnaround/outage or “STO” project.

Critical lessons from this research project are described in Chapter 2. Unique aspects of STO projects are discussed in Chapter 3. A new tool, called the Shutdown/Turnaround Alignment Review or “STAR” Tool, has been developed that can assist in the assessment of readiness of an STO. Information regarding the STAR Tool is included in Chapter 4.

A key activity for R&R projects is the mitigation of risks surrounding the characterization of existing site conditions. A number of current tools and technologies have been identified to help with this effort. These tools and technologies are described in Chapter 5.

Finally, Chapter 6 summarizes the critical issues that must be addressed when conducting R&R projects, and provides a path forward for practitioners. Several appendices provide practical tools to help.

1.2 What Are Renovation and Revamp Projects?

A renovation and/or revamp project is defined as a project that is focused on an *existing* facility. It includes the act, process, or work of replacing, restoring, repairing, or improving a facility with capital funds or non-capital funds. This may include the addition of structures and systems to achieve a more functional,

serviceable, or desirable condition, including improvements in the following areas:

- profitability
- efficiency
- security
- compliance with regulations
- reliability
- safety
- environmental performance.

Approximately 30 percent of all project dollars spent by CII members is on R&R projects.¹

A comparison of R&R projects versus projects in general was recently evaluated by CII. It was found that R&R projects consist of approximately 30 percent of all projects being completed by CII members (by dollar value). R&R projects tend to be smaller in size than typical projects and to have fewer resources dedicated to front end planning. Individual R&R projects can, however, be quite large.

Most CII member companies handle front end planning for R&R projects somewhat differently. These differences can include more local/site management of these projects, more owner/site involvement, and/or greater emphasis on facility or site assessments.

R&R projects are executed for buildings, industrial process, infrastructure, manufacturing facilities, or for other areas. They may be referred to differently in specific industries or applications. Widely used descriptors include:

- retrofit
- shutdown/turnaround/outage
- modernization
- repair project (not routine)
- rehabilitation
- refurbishment
- upgrade
- rebuild
- maintenance project (not routine)
- improvement project
- alteration
- de-bottlenecking project
- modification
- makeover
- overhaul.

¹ “Analysis Supporting Front End Planning for Renovation and Revamp Projects, Part 1,” Research Report 242-11, Construction Industry Institute, Austin, TX, 2009.

- replacement
- reclamation
- redevelopment
- reutilization
- reconstruction
- betterment
- regeneration
- relocation
- restoration
- brownfield project.

1.3 Why Are R&R Projects Unique?

**R&R projects contain unique or increased risks
when compared to greenfield projects.**

For R&R projects, unique or increased risks (to cost, schedule, or quality) appear that are not generally present for greenfield projects. The conditions of the existing site, and in-place equipment, are typically unknown. Older facilities often have unusual safety hazards, uncertain spatial characteristics such as unseen interferences, outdated or inaccurate as-existing condition information, legacy environmental conditions, architectural or historical concerns, or issues with dismantling or demolition.

Additionally, there is an amplified need, in many cases, to coordinate with other ongoing projects at the same site, and with existing plant or facility activities (operations, maintenance, security). Facilities may have unique policies, procedures, or contract and procurement strategies that must be taken into account. Issues of compatibility between new and old equipment and technology must be addressed. Additional risks are outlined in Section 2.1 later in this implementation resource.

The above risk areas increase project complexity, and can manifest themselves in terms of increased costs, project delays, or failures to achieve project goals. Failures are more likely if these risks are not addressed in front end planning. Project teams often refer to the realization of such a risk as a “discovery issue” during later stages of execution of a project, when often they could have been dealt with earlier in the project via good front end planning.

1.4 Shutdown/Turnaround/Outage Projects

Shutdown/Turnaround/Outage projects (STOs) are a subset of R&R projects. These generally have specific time constraints and large business cost drivers for successful completion on a tight schedule. These cost drivers include significant losses of production or sales opportunities resulting from any delays. For these projects, coordination of effort between multiple projects (each with their own unique issues), and with facility maintenance and operations activities, is extremely important. These projects are covered in more detail in Chapter 3.

1.5 Front End Planning

Previous CII research has focused on front end planning as a critical component in the success of projects. Front End Planning is defined as “the process of developing sufficient strategic information with which owners can address risk and decide to commit resources to maximize the chance for a successful project.” CII research indicates that well performed front end planning can reduce costs, lead to less project variability in terms of cost, schedule, and operating characteristics, and increase the chance of meeting a project’s environmental and operational goals. This previous research has led to tools such as the Project Definition Rating Indexes (PDRI²), and the Alignment Thermometer³ to help teams more effectively plan projects.

The FEP process diagram is below in Figure 1.

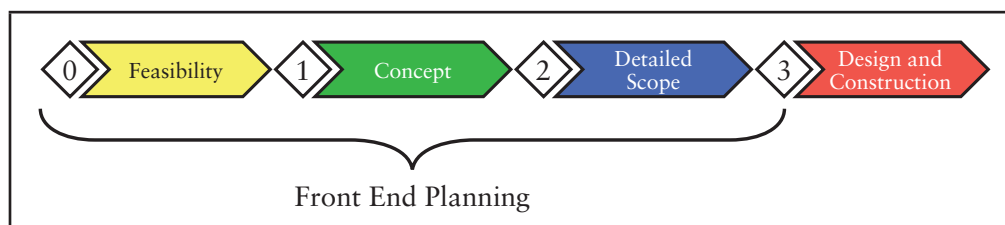


Figure 1. Front End Planning Process

² Implementation Resource 113-2, *PDRI: Project Definition Rating Index – Industrial Projects*, Version 4.0, and Implementation Resource 155-2, *PDRI: Project Definition Rating Index – Building Projects*, Version 4.0

³ Implementation Resource 113-3, *Alignment During Pre-Project Planning: A Key to Project Success*, Version 4.0

The PDRI is a tool designed to measure project scope definition for completeness. It is a comprehensive, weighted checklist of scope definition elements. Projects with low assessed index scores have been found to outperform projects with higher assessed scores⁴.

Fourth editions of the Industrial and Building PDRI have been published to assist project teams that are planning R&R projects.

In the third editions of the Industrial and Building PDRI tools (IR 113-2 and IR 155-2), the PDRI tools incorporated additional questions to be addressed by the project team when working on R&R projects. Consideration of these additional issues will increase the likelihood of success of R&R projects. Unique R&R scope definition issues were added to 27 of the 64 element descriptions in the Building Projects PDRI and 38 of the 70 elements in the Industrial Projects PDRI. An example of a revision made to the PDRI is captured in Figure 2, showing additional issues to consider for R&R industrial projects when considering PDRI element G7 “Piping System Requirements.” Appendix A contains a cross reference of unique R&R risks to applicable sections of the Industrial and Building Project Definition Rating Index (PDRI) where they are addressed. Since its publication of the third edition of IR 113-2 and IR 155-2, CII published IR 268-2, *PDRI: Project Definition Rating Index – Infrastructure Projects*. The software tools of all the PDRI tools have been updated, and all three are now available in fourth editions.

⁴ Research Summary 213-1, *Front End Planning: Break the Rules, Pay the Price*

G7. Piping System Requirements

Piping system stress guidelines and requirements should be provided to ensure that piping system design can be estimated and scheduled. The owner must communicate the standards, methodology, and record documentation required to support the piping systems design effort. Criteria for design of piping systems should include:

- ☐ Allowable forces and moments on equipment
- ☐ Graphical representation of piping line sizes that require analysis based on:
 - ☐ Temperature
 - ☐ Pressure
 - ☐ Cyclic conditions
 - ☐ Flex
 - ☐ Stress
 - ☐ Pulsation
 - ☐ Seismic
- ☐ Other

Additional items to consider for Renovation & Revamp projects

- ☐ Verification of existing conditions: hangers, supports, anchors, wall thickness
- ☐ Field verify existing lines that will be modified and requiring stress analysis back to all anchor points
- ☐ Ensure lines are functioning, available, and active

Figure 2. Sample PDRI Revision showing additional R&R related Questions

This implementation resource is meant to be complementary to the PDRI by focusing on tools and techniques that can be used to effectively plan R&R projects.

R&R Project Risks and Critical Success Factors

As previously mentioned, R&R projects contain unique risks and can present unique challenges to the project team. While typically less costly than greenfield projects, R&R projects tend to be more complex due to their interfaces with an existing facility. This chapter provides details regarding the increased risks surrounding R&R projects and a framework for addressing these risks in a proactive manner.

2.1 Increased Risk Areas for R&R Projects

Table 1 gives a more detailed summary of the risks inherent to R&R projects, with specific examples of how they may be manifested.

Table 1. Examples of Increased Risk Areas for R&R Projects

Risk Area	Examples
Safety	• Unique facility safety rules • Hazardous material removals • Close working environment with operational processes or equipment • Confined space work • Demolition work • Work area congestion • Shutdown/turnaround time pressures and labor fatigue • Undocumented hazards
Security	• Need to maintain operating plant security boundaries • Timing/receipt of deliveries • Division between project area and operating facility • Screening of personnel to allow access to the operating facility

Table 1. Examples of Increased Risk Areas for R&R Projects (continued)

Risk Area	Examples
Existing conditions	• Drawings do not match field conditions • Aging effects on old systems, structures and components • Isolation points inoperative, degraded, or passing • Clogged piping • Pipe walls/structural steel thinned • Tank liners degraded • Sumps clogged • Supports broken • Foreign or hazardous material in systems • Poor subsurface conditions (soil conditions, interferences) • Degraded insulation • Undocumented embedded components • Poor water quality • Poor utility availability • Floors, surfaces uneven or not level
Coordination	• Impact of tie-ins to operating plant • Availability of operating plant personnel to support tie-ins and other interface issues • Shutdown/turnaround/outage constraints • Other parallel planned project or maintenance impacts • Owner documentation or procedural requirements (facility specific) • Transportation issues (to site and within site)
Compatibility	• Current technology interfaces with old • Materials/chemicals not compatible with existing plant or facility
Contract and Procurement Strategies	• Operating facility may have preferred technology, construction trades, vendors, and/or unions • Applicable code and standard changes from date of original construction may make procurement to original specifications impossible • Project contract strategy needs to be consistent with integrated facility work program • Need to perform good site characterization for vendors to provide competitive “fixed price” quotes
Environmental Issues	• Legacy environmental spills/hazards • Regulations surrounding changes to plant
Historical/ Archeological Concerns	• Need to maintain/protect items of historical importance • Unmarked gravesites or areas of archaeological interest
Dismantling/ Demolition Requirements	• Systems/structures/components to be removed (either permanently or temporarily) for new equipment • Impact on operating facility during demolition/dismantling work

2.2 Critical Success Factors

In order to address the unique risks for R&R projects as identified above, the research team has identified a number of critical activities during front end planning that need to be completed. These include the following tasks:

- Ensure alignment and conduct teambuilding.
- Choose contract strategy for project constraints.
- Define existing conditions.
- Identify and engage key stakeholders.
- Follow a defined front end planning process.
- Define critical scope issues.
- Ensure labor and material availability.
- Explore alternative construction methods.
- Apply leadership and experience.

It should be noted that many of these strategies or critical activities apply to all types of projects. The issues unique to R&R projects in terms of these issues are discussed below.

2.2.1 *Ensure Alignment and Conduct Teambuilding*

Alignment is defined as “the condition where appropriate project participants are working within acceptable tolerances to develop and meet a uniformly defined and understood set of project objectives.”⁵

One way to align a project is through teambuilding. Teambuilding is a technique used on projects to establish trust and cultivate relationships among stakeholders. This is especially valuable when the project team is new or from outside of the facility where the project will take place. Teambuilding also can help establish effective communication between the project team and project stakeholders. The teambuilding sessions can range from a wide variety of activities including project cookouts, sporting events, and offsite meetings. Teambuilding is not always effective, especially if stakeholders are not committed to the concept, but if pursued

⁵ *Alignment During Pre-Project Planning, A Key to Project Success*, Implementation Resource 113-3, Second Edition, Construction Industry Institute, Austin, TX, 2005

early in a project it can be effective in improving alignment. This is particularly important for R&R projects because of the need to coordinate and communicate with tenants, local managers, and employees at the existing facility.

Conducting formal PDRI sessions at appropriate project stages can also promote alignment and teamwork between project team members and key stakeholders. In fact, almost any session (e.g., project kick off meetings, value engineering sessions⁶, and constructability reviews⁷) that gathers the project team together to build relationships and discuss project goals can assist.

Teambuilding and communications are sometimes more difficult for R&R projects, but also can provide a large benefit.

R&R projects often involve increased requirements to interface with local engineering and operations and maintenance staff, making alignment more difficult. Key site stakeholders can be distracted by other duties during project planning, but later may invoke unexpected requirements during project execution. All key stakeholders need to feel involved as contributing members of the project team, and participate in front end planning to help ensure project success.

STOs have an additional requirement to ensure alignment around the goals of the STO. If not planned properly, multiple projects and maintenance activities can compete for the same resources during an STO. The various work groups involved need to work as a single team and be aligned around a single schedule and the overall goals of the STO.

2.2.2 Choose Contracting Strategy for Project Constraints

Selecting proper contract strategy requires choosing the right form of contract so that risks among the parties in a project are appropriately allocated. CII's Project Delivery and Contract Strategy (PDCS) tool⁸ can help to identify the contract types that offer the best chance of meeting a given project's requirements.

⁶ *Value Management Toolkit*, Implementation Resource 184-2, Construction Industry Institute, Austin, TX, 2003

⁷ *Constructability Implementation Guide*, Special Publication 34-1, Second Edition, Construction Industry Institute, Austin, TX, 2006

⁸ *Owner's Tool for Project Delivery and Contract Strategy Selection User's Guide*, Implementation Resource 165-2, Construction Industry Institute, Austin, TX, 2003.

Risks to a project are increased if the chosen contract strategy is not a good match to the project's drivers and goals.

R&R projects often require specific preferred suppliers, a specific labor force to be used, hours of work, unions to be used, pre-purchasing of material, and remediation, demolition, and parallel prime contracts (where the facility owner or a contract management agent serves as a general contractor for the facility). Close coordination with local purchasing organizations, operations and maintenance staff, and between contractors is required to ensure the right strategy has been chosen.

2.2.3 Define Existing Conditions

A thorough definition of existing conditions is one of the key factors in R&R project risk mitigation in that it reduces the possibility of surprises or “discovery issues” later on. A vast number of issues can have an impact on a renovation and revamp project, however a small amount of work in this area can yield large savings later on in the project.

Site conditions need to be thoroughly investigated, or other risk mitigation steps taken.

During scope definition, existing site conditions should be explored thoroughly where practical, and conditions determined. Where conditions cannot be predetermined economically or safely, a risk mitigation plan should be put in place to deal with potential issues. Such a plan might include designing to minimize the impact of embedded or underground structures, training for contingency activities on mock-ups, purchasing of contingency spare parts, and/or allocating contingency time or money to the project to address high-risk areas.

Project teams are encouraged to use new and novel tools and technologies to help in the investigation of existing site conditions. Chapter 5 contains a discussion of some project condition investigation tools available that can assist in this area.

2.2.4 Identify and Engage Key Stakeholders

A stakeholder is defined as any person who has influence on the course of an event and/or a material interest in that event's outcome. All projects have stakeholders, and the larger the project, the more stakeholders in general. Each stakeholder in a project must be a vital contributor. If a project does not have all key representatives participating in front end planning, issues may be forgotten or unresolved, and the project will suffer.

Clear definition of what is in and what is out of scope should be made early in the front end planning process. It is important to have all key stakeholders involved in project decisions, and even more important to have alignment between these stakeholders. This is to ensure that disagreements regarding what the project will ultimately deliver do not later occur.

For R&R projects in particular, individuals involved may be tempted to increase scope to fix non-value added issues with the existing facility; many times, these issues would be more appropriately dealt with by the facility's operating budget or as standalone projects.

The number of stakeholders for R&R projects is generally larger than for greenfield projects.

It should be noted that the number of stakeholders for R&R projects is generally larger than for greenfield projects. Local operations, maintenance, engineering and procurement staff normally need to be involved as part of front end planning and later during project execution. These interfaces add to the complexity of planning and executing such projects.

2.2.5 Follow a Defined Front End Planning Process

The front end planning process is characterized by a formal progression that guides an organization through various planning efforts with regular "gate checks" designed to ensure readiness for the next phase of the project. A good process will require the use of checklists to ensure that defined deliverables are provided. The process should include such steps as defining a charter, developing objectives, defining scope, identifying stakeholders, documenting deliverables, project estimating, and planning for project execution.

Since many R&R projects are smaller, shorter in duration, and performed by local staff who may not typically oversee larger projects, there can be a tendency to skip some or all of these planning steps by project team members.

Many of the critical success factors listed herein are interrelated. If the front end planning process is not well defined, then there may be adverse effects on scope definition, stakeholder identification, definition of existing conditions, and contracting strategies. A properly executed and well-defined front end planning process will positively impact the other critical success factors.

2.2.6 Define Critical Scope Issues

The scope of a project directly impacts its cost and schedule. If a project has a poorly defined scope, it is destined for failure. Effective communication between all stakeholders can aid in the scope development process by identifying key project elements, discovering unforeseen conditions, and mitigating potential problems. A well defined scope should include early identification of all project elements so that project team members can resolve any differences regarding what the project will ultimately deliver (and not deliver). Of special importance for R&R projects is the identification of what items are not in the scope of the project, as there can be a tendency during project execution of such projects to inappropriately include non-value or maintenance items in the project.

For R&R projects, team members need to address how the project will interface with existing facility operations or functions within the defined project scope. Increased efforts typically need to be applied to obtain a thorough understanding of local site conditions. Since R&R projects tend to be smaller than greenfield projects, there may be a tendency to skip or spend minimal time on these efforts. This tendency should be recognized up front and avoided if at all possible.

Industry tools such as the Project Definition Rating Index (PDRI) are available to assist the stakeholders in scope definition. The PDRI can contribute to a well defined scope if used properly. Many CII organizations have adopted this tool and others have developed internal proprietary checklists that perform a similar function.

Managing the scope for an STO R&R project is complex because of the multiple projects that are normally involved. Lack of scope definition on a single project within the STO can detrimentally affect all others. RT242 developed the STAR Tool to assist planners in determining if the STO scope is sufficiently defined. Refer to Chapter 3 for a more detailed discussion of specific success factors for this subset of R&R projects.

In addition to specific scope issues, project drivers need to be clearly defined and understood by the project team. A project driver can be defined as the “why” of project execution. Project drivers, which are normally identified in the front end planning phase of the project, can affect an R&R project in terms of specific design solutions utilized, sources of funding, and contract strategy.

From a design perspective, a lack of understanding of key project drivers can result in more expensive and elaborate solutions to problems when simpler, more cost-effective solutions may suffice. For R&R projects, specific knowledge of local plant or facility conditions (as provided by local staff or by detailed site investigations) can yield easier and cheaper projects. Projects with only minor alterations can often be constructed to earlier regulations, codes, or standards, thus yielding lower overall costs. Value engineering seminars⁹ attended by local facility staff can help further explore or challenge the appropriateness of design solutions.

Funding itself can be a project driver. Company or government capitalization rules and budget allocations can drive the scope and/or extent of the planned work. In some cases, funding can only be provided through operations and maintenance funding mechanisms, again leading to more project complexity.

A project driver can also have an effect on the schedule. If the project is a regulatory project, the date of mandatory completion becomes the main focus of the project. Schedule drives the project (due to the regulatory date), and the project team may have to install temporary systems as interim measures to ensure regulatory compliance. These measures can cause cost increases and schedule delays.

⁹ CII *Value Management Toolkit*, Implementation Resource 184-2, Construction Industry Institute, Austin, TX, 2005

The requirement to maintain existing operations or to minimize shutdown/turnaround duration of an existing facility while completing project work is often a driver that is unique to R&R projects.

2.2.7 Ensure labor and material availability

One important requirement of R&R projects is the need to carefully review interfaces with, and tie-ins to, the affected existing facility. Older facilities may require tie-ins or interfaces with old or obsolete equipment, or equipment that may need substantial refurbishing. Such facilities may have utilities and other equipment installed that do not have readily available spare parts (e.g., old style circuit breakers may not be available to supply new loads being installed as part of the new project), they may have been constructed with older materials that are no longer available or may now be considered hazardous, or they may have undocumented or out of date design information.

A plan needs to be developed to ensure that the required compatible parts and materials are available when needed. When introducing new technology to an old facility, a phased approach involving technology trials may be beneficial.

For shutdown/turnaround/outage projects, critical facility or trades execution labor is often controlled and allocated by the shutdown/turnaround manager, and not by individual project teams. Individual project teams need to understand the labor constraints that they will be working under, and develop contract and resource allocation strategies to effectively deal with them.

Additionally, key material (and key contingency material) should be physically confirmed on site, accepted by the execution work force, and staged appropriately at the worksite prior to the STO.

2.2.8 Explore alternative construction methods

“Business as usual” construction approaches cannot always be expected to work well in R&R projects. Consideration of alternative and creative project execution methods early in the planning process will be valuable in identifying effective solutions to unique problems. CII Implementation Resource 171-2, *Prefabrication, Preassembly, Modularization, and Offsite Fabrication: Decision Framework and Tool*, can be consulted for assistance in this area.

For shutdown/turnaround projects, where on-site construction schedules are typically time-limited, the project team will benefit immensely if alternate construction methods are employed that minimize “in-facility” or “in-STO” work. These would include designing for modular construction, prefabricating as much as is possible off site, and/or designing to allow as much installation work to proceed as possible prior to the planned shutdown/turnaround. Newer technologies such as using 3D laser scanning dimensional control systems (discussed in Chapter 5) that minimize fit-up issues can be used to advantage in this area.

2.2.9 Apply Leadership and Experience

For a project team to be efficient and effective, it is critical to have effective leadership and experience in key disciplines. The project manager needs to identify the expertise required and bring together team members who possess the required experience and skills. This is especially important when the project faces tight time and cost constraints, and/or when the project poses special challenges in execution.

For R&R projects, experience at the existing facility allows project team members to anticipate potential problems and/or react quickly to them as they arise. Key disciplines would include design, project controls, procurement, operations, maintenance, and construction.

Shutdown/Turnaround/Outage Critical Issues

3.1 Introduction

Shutdown/Turnaround/Outages (STOs) are known by many different aliases depending upon the industry or geographical location. For the purposes here, STO refers to a project or portion of a project(s) that is executed during a planned disruption in normal use or operation, where return to service is a business priority. It is common to have several projects being executed during an STO. This is due to the requirement for facility to be in a mode other than its normal operating mode to facilitate project tie-ins. Normal maintenance activities usually take place during this period as well, further complicating the execution of the STO. Many organizations treat STOs as a project even if they contain only maintenance activities. This is done in order to bring project management discipline to the large investment in the facility asset.

STOs are considered a subset of renovation and revamp projects.

From a project perspective, STOs are considered a special subset of renovation and revamp projects. During an STO, timelines are a major constraint, activity levels tend to be much greater, focus is much broader, and project risk levels are typically higher. Some of the critical issues that set STOs apart will be briefly examined in the following section.

3.2. STO Critical Issues

STOs have many unique characteristics that must be managed to ensure project success. Approaching an STO using only “greenfield” project management techniques may not by itself lead to success. The following are some of the critical issues that need to be considered when planning an STO.

- a) **Alignment:** During planning for most projects, one project is to be executed during a specific period. In the case of an STO, usually many individual projects and maintenance activities will be executed in the same period. From a management perspective there is no longer a single focus, however, staff or contractors working on individual projects may continue

to maintain single-project focus. The organizational hierarchy and goals of the STO need to be understood by the various project teams.

- b) **Safety Management:** The nature of STOs imposes unique safety challenges. Such periods of intense activity, with possibly competing objectives, may compromise safety if not actively managed. Consideration needs to be given during the STO to an overall safety program and an enhanced emergency response capability.
- c) **Contracting Strategies:** Multiple contractors working on an STO with different contracting strategies may drive behaviors that are not aligned with the overall objectives and priorities of the STO. Interfaces between projects, contractors, and the facility need to be planned and managed.
- d) **Availability of Resources:** An STO is characterized by a relatively short period of intense activities, and availability of required trades, engineering staff, specialized contractors, or equipment may be in short supply. In these periods of high demand, productivity or quality can suffer, negatively impacting cost and/or schedule. Additionally, resources to provide site training or orientation prior to and during the STO may be taxed during these periods. In some cases, input from these training resources may be required in the front end planning stages of the STO.
- e) **Logistics:** Due to competing priorities of projects and maintenance activities, detailed, integrated plans are needed that choreograph the various activities. Coordination of lifts, swing space requirements, and other logistical issues must be understood prior to the STO. Material movement and staging prior to and during the STO must be coordinated.
- f) **Space Allocation:** Real estate (space) will often become premium for everything from facilities, equipment staging, part staging, work areas, and laydown areas to pedestrian and traffic flow. A common space allocation process for the STO is recommended.
- g) **Fixed Resources:** Competition for the use of fixed cranes, service air, water, power, and so on can result in cost or schedule impacts. Availability of these services can be affected by the work scope of the STO, as systems are taken out of service for maintenance or project tie-ins.
- h) **Control of Work Zone:** It is common to have multiple work zones controlled by multiple contractors during an STO. Consideration needs to be given to how these work zones will be controlled to ensure safety

and efficiency, including pedestrian traffic, material movement, and work space availability.

- i) **Lock Out/Tag Out Requirements:** STOs can be complex, with diverse work in many locations on many different process systems. Some of these activities may not normally occur during online maintenance activities. This may increase the complexity of the lock out/tag out requirements. Older facilities may have degraded conditions (e.g., passing isolations) that may render the most efficient or planned lock-out isolation points unavailable. The availability/condition of critical project lock out/tag out isolation points should be confirmed prior to the STO where possible.
- j) **Site Condition Knowledge:** Often STOs are schedule-constrained with a heavy penalty for delay. Accurate knowledge of site conditions is critical to maintaining schedule and cost. Inventories of designated substances (asbestos, lead paint), accuracy of drawings, and contractor knowledge of site operations, maintenance, and safety procedures are some of the knowledge of site conditions issues that may have an impact on the STO.
- k) **Unplanned/Discovery Work:** Maintenance activities are usually conducted during an STO. The possibility of unplanned/discovery work as a result of maintenance or project activities is great, and these can impact the overall scope of work to be conducted during the STO. Project interfaces to the existing facility may turn out to be different than planned, and project schedules may need to be adjusted with little notice. Risk mitigations plans should be in place, and procurement and contract strategies should be aligned to effectively manage such situations.
- l) **Environment Management:** Special precautions may be necessary to ensure the STO does not adversely affect the environment. Such items as noise, dust, and hazardous material control need to be managed. The scope of the STO needs to be understood to ensure that environmental control systems are not inadvertently taken out of service.
- m) **Permit Requirements:** Permits required by the local, state/provincial, or federal regulatory bodies required to construct, maintain, and operate the facility need to be obtained, in most cases, prior to the start of construction. Since several projects making up the STO may have permitting requirements, an integrated plan generally is required.
- n) **Security:** The intense nature of the STO may influence/site security arrangements. Additional resources may be required to process personnel, tools, and equipment in and out of the facility.

- o) **Traffic Control:** Consideration needs to be given to traffic control entering and on the facility site, as well as parking during these periods of intense activities.
- p) **Communication Strategy:** Effective communication strategies from the workforce up to management levels are required to be in place prior to the STO. These include protocols for routine workforce communication, STO progress reporting, work group handoffs, and urgent item resolution (e.g., delays, unforeseen conditions, and labor or material shortages).
- q) **Project Controls:** Reporting processes for controlling cost and schedule need to be flexible enough to supply the required information at the required time intervals for the overall STO and for individual projects as required.
- r) **Schedule Integration:** Integration of all the specific project/maintenance STO work schedules is a requirement. The sequencing of predecessor and successor activities needs to support the goals of the STO rather than individual projects. The critical path needs to be identified and supported by the contracting strategies of all the participants in the STO.
- s) **Cost Control:** The constraints imposed by the STO may put upward pressure on individual project costs. This risk needs to be understood and accounted for, and the individual projects aligned with the contracting strategies and the objectives of the STO.
- t) **Scope Control:** There is usually a large desire to avoid future shutdowns or outages for the facility, and to complete as much work as possible during the STO. The desire to complete discovery/unplanned work or perceived “key” projects may adversely affect the overall STO cost and schedule. Strong control of scope changes is required during STO to ensure the STO cost and duration is kept consistent with organizational business drivers.
- u) **Procurement Plan:** The fixed return to service date and the interdependencies imposed by projects and maintenance activities require a well-functioning procurement plan and organization. The procurement plan is required to be aligned with the integrated schedule, and be adaptable to unforeseen events. The procurement organization needs to be able to deal with urgent material requests and changes to contracts during the STO to effectively deal with discovery work. To the extent possible, potential material discovery risks (e.g., spare parts that are likely to be required) should be evaluated and actively managed prior to the STO.

- v) **Commissioning Plans:** The sequencing of the commissioning and startup/return-to-service activities needs to be integrated and supported by a single plan.

Project teams that address these STO critical issues will have a better opportunity for success.

3.3 STO Risk Mitigation Strategies

Renovation and revamp projects require a high level of planning to minimize the risks imposed by interfacing with existing facility systems. They are often performed in conjunction with other ongoing projects. STOs are a special subset of renovation and revamp projects and the list of critical issues in Section 3.2 identifies numerous areas where risk mitigation may be required.

With STOs posing a large number of risks, the first level of risk mitigation should be to design for minimizing the amount of work required to be performed during the STO. This may not be the easiest or the cheapest solution for individual projects, but it may be the best overall for the facility. The risk imposed by executing construction during an STO needs to be considered during the design review process and later during constructability reviews.

For work scope that must be executed during the STO, effective early planning will improve the STO performance in terms of both cost and schedule. The CII membership recognizes the importance of scope definition during the early stages of a project and its potential impact on project success. The Project Definition Rating Index (PDRI) allows a project planning team to quantify, rank, and assess the level of scope development on individual projects prior to beginning detailed design and construction. Since its third edition, the PDRI has included unique elements of renovation and revamp projects, with STO-specific issues as a subset.

If similar STOs will be executed over a period of time, the development of a standard STO schedule “template” that incorporates optimized best practices is desirable.

During the STO, special organizations such as a fully staffed “Outage Control Center,” with empowered individuals from operations, maintenance, engineering, procurement, and other support groups may be put in place to facilitate communications and quick resolution of issues. Special communications protocols

may be put in place to ensure issues are quickly raised to STO management, who can bring assistance to bear quickly on the problem. Detailed STO metrics may also be routinely used to track STO preparations, progress, and other key issues (e.g., material availability, engineering product availability, and low level safety incidents). Finally, specialized maintenance crews may be established to address highly complex jobs that are critical to the STO.

Another tool for planning and risk mitigation that has been developed for use with the PDRI during an STO is the Shutdown/Turnaround Alignment Review (STAR). STAR provides an assessment of key planning attributes unique to STOs, leading to earlier risk identification and mitigation. The following chapter describes the STAR Tool.

STAR provides an assessment of key planning attributes unique to STOs. This leads to earlier risk identification and mitigation.

Shutdown/Turnaround Alignment Review (STAR) Tool

4.1 Background

The STAR Tool (see Appendix B: Shutdown/Turnaround Alignment Review or “STAR” Tool) provides an “umbrella” evaluation method to test the alignment and preparedness of multiple projects to move forward into detailed design and execution of a shutdown/turnaround/outage (STO). As previously discussed, an STO is a unique event where multiple projects and maintenance activities converge into a period of time, resulting in “time-constrained,” integrated, and often rapid schedule execution of multiple activities. Individual projects within the STO must compete in a “one-to-many” relationship as they vie with others for resources, space, or equipment.

The STAR Tool provides insight, management guidance, and a common ground for communication between project teams as they work together to meet customer expectations during an STO. It is complementary to the PDRI, which provides an assessment of execution readiness of individual projects.

The STAR Tool would normally be used by the STO manager or an individual who is intimately knowledgeable with the scope and objectives of the STO. It would be most effective when a team of representatives for all the work that will be executed during the STO get together to complete the STAR assessment. Representation of contractors would be considered essential input to the assessment. The STAR assessment also serves as a good alignment exercise for the STO team to ensure the objectives of the STO are communicated to the individuals involved.

The STAR Tool was initially developed by a sub-team of 10 RT242 research team members specializing in the planning and implementation of STOs. Subsequently, a series of four external validation workshops were held to prioritize the tool as well as provide input and suggestions for refinement. The participants at the workshops included 67 individuals from 39 separate organizations with combined project management experience of over 1,300 years. After development, the tool was tested on several actual projects, including both ongoing and completed STOs.

In all cases the tool showed its value in STO planning activities. More details of this development activity can be found in CII Research Report 242-12¹⁰.

4.2 STAR Tool Timeline

The STAR Tool can be employed at various times in the front-end planning phases of the individual projects. Figure 2 illustrates how various projects that comprise an STO are often in varying degrees of preparation. The STAR Tool can be used to assess the risks and readiness of the overall STO. The STO manager will decide when to undertake a STAR assessment, generally 12–18 months prior to the STO, and will review each project and work scope in terms of its impact to the overall STO readiness. Actions can be taken to bring the projects into alignment with STO preparations. The process can be repeated a number of times as desired to track improvements in STO preparation.

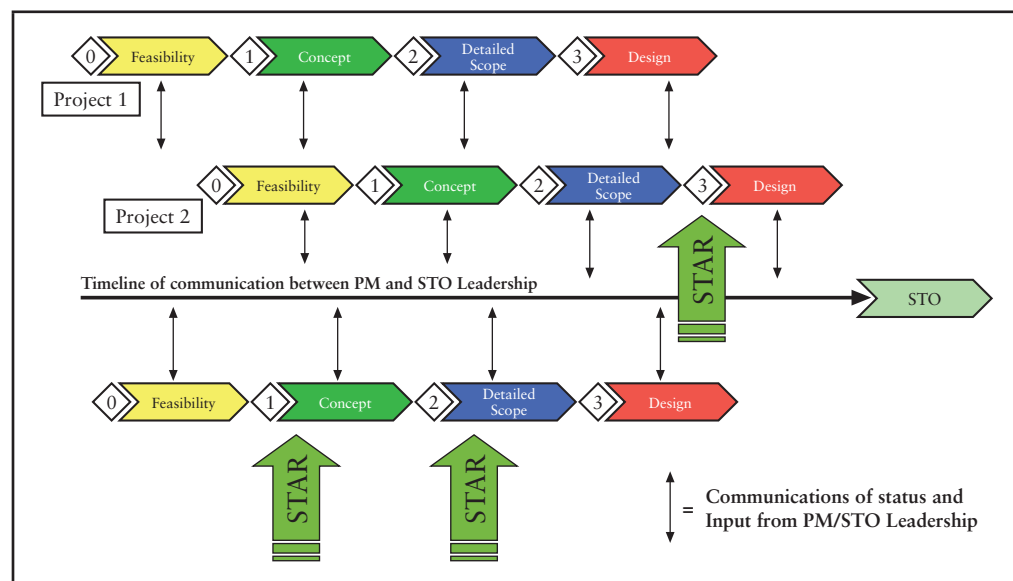


Figure 2. STAR Tool Timeline

4.3 Critical STO Areas

Nine critical areas for success have been identified for a joint assessment of the multiple projects that will eventually converge during the STO. This assessment provides a venue or forum where multiple projects can be reviewed collectively

¹⁰ “Analysis Supporting Front End Planning for Renovation and Revamp Projects, Part 2,” Research Report 242-12, Construction Industry Institute, Austin, TX, 2009.

in the early stages of their preparedness, leading to identification of problem areas, potential conflicts in priorities, and, hopefully, win-win solutions involving the key stakeholders/customer. The nine categories to be evaluated are listed in Table 2.

Table 2. Critical STO Categories

- | |
|---|
| <ol style="list-style-type: none"> 1. Design for Constructability Analysis 2. Permit requirements 3. Equipment and material status 4. Procurement procedures and plans 5. Project control requirements 6. Engineering/construction plan and approach 7. Shutdown/turnaround/outage requirements 8. Commissioning 9. Startup requirements |
|---|

Identified within each of these categories are supporting attributes or elements for evaluation that, when reviewed together, provide an overall summary of risks. With this assessment, informed decisions can be made, needed actions for improvement can be identified, and identification of priorities between competing projects discovered.

Each of the nine categories in Table 2 has an assigned “value” or “prioritization” based on a total score for all categories of 1000 points. These prioritization values were developed in the workshops described earlier.

4.4 Example Assessment Using the Tool

Consider for example that you are a member of team responsible for evaluating an electrical generating facility’s STO preparation. The STO consists of primarily routine maintenance activities, but also contains two major projects – replacement of the unit’s old analog boiler/steam generator level controllers with new electronic models, and installation of a new pump seal design on the main boiler feed pumps. Assume that plans have been formulated by the project teams for the commissioning of their individual projects, required vendor and

engineering support for the controller replacement and pump seal work has been arranged but not yet scheduled to the specific day, and an integrated plan showing all STO commissioning activities is not yet available.

Your responsibility is to evaluate how well the STOs Commissioning requirements have been identified and defined. This information is covered in Category 8 of the STAR Tool as shown below and consists of four elements: “Sequence of Individual System Turnovers Defined,” “Required level of involvement defined for constructor, vendor, designer, inspection agency, and owner,” “Acceptance/approval criteria and responsibilities defined,” and “Other.”

STAR Tool (continued)							
Categories/Elements for Review:	N/A	High Performing	Meets Most	Meets Some	Needs Improvement	Not Acceptable	Comments:
8. Commissioning <i>Evaluate each of the line items below based on a collective impact of the multiple projects involved. The owner's required sequence for turnover of the project for commissioning activities has been developed and incorporated into overall STO schedule.</i>		1	18	37	55	73	
A. Sequence of individual system turnovers defined							
B. Required level of involvement defined for constructor, vendor, designer, inspection agency, and owner in:							
B1. Pre-commissioning							
B2. Training							
B3. Testing							
C. Acceptance/approval criteria and responsibilities defined							
D. Other							

To complete the STAR Tool assessment for Category 8, Commissioning, follow these steps:

Step 1: Read the description of the category and element in Appendix B.

Step 2: Assess each category line item relative to its stated objectives and to the preparedness of the entire suite of projects making up the STO; select the rating for each line item. Rating definitions are given in Table 3.

Identify any critical deficiencies in elements that would prevent the STO from proceeding without a major recovery for that element and provide comments.

Table 3. STAR Tool Rating Definitions

Readiness Rating	Description
NA	Not applicable
High Performing	Project meets or exceeds the objective(s) or expectations.
Meets Most	Project consistently meets the objective(s). Some areas may need additional minor attention.
Meets Some	Project partially meets the objective(s) or expectation. Without improvement, success could be in jeopardy.
Needs Improvement	Project is not consistent in meeting the objective(s) or expectations. Without improvement, project is at risk. Actions to meet expectations are required.
Not Acceptable	Project is consistently below expectations and performance is unacceptable. Success cannot be achieved in current state. Actions are required to improve.

For our example:

- Element 8A: Individual project commissioning requirements have been defined, however an integrated plan detailing how these projects will be turned over has not. Readiness Rating = “Needs Improvement.”
- Element 8B: Vendor and engineering support for commissioning has been arranged but not yet scheduled “to the day.” There are no expected issues with this planned scheduling within a two-week window, however, if the STO extends beyond this window, a critical resource may not be available. Readiness Rating = “Meets Some.”
- Element 8C: Commissioning requirements for the projects have been clearly defined. It has been confirmed by the project teams and the STO plant operations that the two projects do not interfere with each other or with planned maintenance activities Readiness Rating = “High Performing.”
- Element 8D: No other issues with respect to commissioning have been identified. Readiness Rating = “N/A.”

Step 3: Place a checkmark (✓) in the STAR Tool element line items according to their corresponding level of readiness.

STAR Tool (continued)							
Categories/Elements for Review:	N/A	High Performing	Meets Most	Meets Some	Needs Improvement	Not Acceptable	Comments:
8. Commissioning <i>Evaluate each of the line items below based on a collective impact of the multiple projects involved. The owner's required sequence for turnover of the project for commissioning activities has been developed and incorporated into overall STO schedule.</i>		1	18	37	55	73	
A. Sequence of individual system turnovers defined					✓		
B. Required level of involvement defined for constructor, vendor, designer, inspection agency, and owner in:							
B1. Pre-commissioning				✓			
B2. Training				✓			
B3. Testing				✓			
C. Acceptance/approval criteria and responsibilities defined		✓					
D. Other	✓						

Step 4: Record follow up actions on the STAR Tool Action Item Page as the team assesses each category and its corresponding elements. It is important to record the action required, and to assign responsible individuals, due dates, and any clarifying comments such as management expectations, required inputs, and criticality on the action item page.

Step 5: For each category, once all the sub-issues or elements have been addressed, circle the appropriate overall team rating for the category considering ALL projects to be executed during the STO.

For the electrical generating station example, the team assessed the overall rating for this category to be “Meets Most,” with a resultant score of 18 points.

STAR Tool (continued)							
Categories/Elements for Review:	N/A	High Performing	Meets Most	Meets Some	Needs Improvement	Not Acceptable	Comments:
8. Commissioning <i>Evaluate each of the line items below based on a collective impact of the multiple projects involved. The owner's required sequence for turnover of the project for commissioning activities has been developed and incorporated into overall STO schedule.</i>		1	18	37	55	73	
A. Sequence of individual system turnovers defined					✓		
B. Required level of involvement defined for constructor, vendor, designer, inspection agency, and owner in:							
B1. Pre-commissioning				✓			
B2. Training				✓			
B3. Testing				✓			
C. Acceptance/approval criteria and responsibilities defined		✓					
D. Other	✓						

Step 6: Complete the above process for all nine categories. **Add the category priorities for each of the nine STO categories to obtain an overall “Total Points Achieved” rating for the STO.** The rating indicates relatively how well the STO is prepared for execution, with a higher rating meaning more uncertainty.

Step 7: **Take action.** Categories with low overall states of readiness for the STO probably need more work. **Develop risk management plans to address the unacceptable risks identified by the STAR Tool.** The STO manager may choose to monitor the risks through established processes. Alternatively the Manager may choose to do additional periodic STAR assessments as the STO approaches to ensure the risks have been mitigated to acceptable levels, and that new risks have not emerged.

A sample risk register/action list for our example is below:

Action Items and Required Follow-up					
Category/ Element:	Rating:	Issue/ Action Item Description:	Responsibility Assigned:	Due Date:	Status/ Comments:
8A	Not Acceptable	Integrated commissioning plan not issued. Require Rev. 0 commissioning plan issued for review and formally issued	JD (STO Planning: to issue) DC/GM/AC (Projects/Ops/ Mtce: to review)	April 12	Reviewers need to review within 1 week of receipt. Draft to be sent out by JD by April 2.
8B	Meets Some	(a) Identify to Projects the scheduled days engineering and vendor support will be required	CP (STO Planning)	April 22	
		(b) Confirm vendor availability for project support up to 15 Sep,	DC (Projects)	April 30	May require contract change. DC to confirm.

A state of readiness in Columns 1–3 (High Performing, Meets Most, or Meets Some) may be acceptable to management depending on the importance to the STO. A state of readiness in Columns 4 and 5 (Needs Improvement or Not

Acceptable) needs definite improvement or may risk poor execution of the STO depending on the importance of the line item to the STO. One or more line items in this column could be grounds for a “no-go” decision.

A sample of a completed STAR Tool can be found in Appendix C: Sample of a Completed “STAR” Tool.

4.5 Advanced STAR Tool Functionality

An Excel version of the STAR Tool has been published in conjunction with this implementation resource. The Excel version provides some advanced functionality, including the following:

- ability to adjust weighting of individual elements.
- automatic calculation of STAR Tool scoring.

Detailed instructions regarding the use of the advanced STAR Tool functions are included in the STAR Tool help tab within the Excel version.

Project Condition Investigation Tools

5.1 What Project Conditions to Assess

Existing facility conditions pose a unique risk issue for R&R projects.

Existing facility conditions pose a unique risk issue for R&R projects. Unknown subsurface conditions, facility configuration, and degraded equipment or systems can threaten the successful completion of an R&R project. Effective front end planning requires the project team to perform a comprehensive assessment of existing site and equipment conditions. The assessment must be based on a detailed investigation of the following six categories of project conditions:

1. **Underground Conditions** – Underground or embedded utilities, structures, and other unknowns are potentially dangerous and expensive to address if found during construction. For R&R projects, a detailed subsurface investigation should be performed to identify and locate various utilities (water, sewer, gas, electrical power, fiber optics), tanks, embedded structures, abandoned structures, hazardous materials, and items of historical or archaeological interest.
2. **Integrity (Mechanical/Structural/Electrical)** – The current condition of existing mechanical and electrical systems, structures, and their components must be assessed in terms of their fitness for further use. The assessment should determine the potential for failure and need for replacement or refurbishment. This assessment should include all sub-components as well as the potential for changes in material properties having occurred since original installation. These may include damage or dimensional changes caused by corrosion, erosion, heat, fretting, vibration, chemical attack, and radiation, as well as the existence of internal flaws, leaks, cracks, clogs, or material fatigue.
3. **Restricted Access** – R&R projects often involve tasks that must be performed in restricted or difficult areas due to safety hazards (e.g., elevation, temperature, radiation, hazardous chemicals) and/or inherent security issues. Methods that allow remote evaluation of conditions and/or remote access to these areas can enhance the understanding of