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Process Improvement for Power Plant Turnaround Planning and Management

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Abstract: Turnarounds are unique maintenance projects with a high probability of scope change, time delay, and cost overrun. Negative effects stemming from such uncertainties can be mitigated by following best practices for turnaround planning and management. There has been no comprehensive review of best practices for turnaround planning and management in past research. Our review presents guidelines and recommendations based on existing best practices to support managers and engineers involved in turnarounds. Because they are based on proven best practices, implementation of the recommendations should improve power plant turnaround planning and management processes, leading to better project performance. Our paper compares planning and management practices followed in a real turnaround project case to the best practices in order to find gaps and commonalities; the systematic methodology we propose can be implemented by other companies involved in turnaround projects in order to improve their planning and management processes.

Keywords: Best practices, turnaround projects, planning, management, process improvement

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1 INTRODUCTION

Turnarounds, also known as shutdowns or outages, are unique and complex maintenance projects that are performed within short durations and with high intensity in scheduled activities. Unfortunately, turnaround projects are very likely to suffer significant impacts on both incurred cost and execution time. Incurred cost may be impacted by problems such as loss of production during turnaround execution and scope change due to the discovery of unanticipated mechanical issues upon cleaning and inspection of machine parts that are not visible during operation. Any changes in scope also impact execution time. Oliver (2002), in a paper that revealed how turnaround project success depends on complete planning mentioned that "organizations that complete turnarounds on time, on budget, and without surprises invariably have a defined work process and adhere to it". Thus, it is important to have an established process for turnaround planning and management; this process can be optimized by following proven best practices. Other authors have pointed out the escalating need for best practices as a result of the dwindling numbers of the skilled workers currently available: "the skilled workforce attrition that the industry faces today magnifies the risks, increases the need for best practices, and calls for a new paradigm: process- and unit-specific knowledge transfer" (Cormier and Gillard 2009).

Following best practices of turnaround planning and management will contribute to positive impact on cost of turnaround projects. Turnaround project cost includes both the temporary loss of production and the cost of the turnaround itself, so any delay in turnaround execution will result in higher costs. However, two characteristics of turnaround projects are particularly likely to result in project delay and consequently higher project cost. One characteristic is the unknown scope of work. As mentioned by Elshout and Garcia (2009), despite considerable improvement in the techniques for predicting corrosion rates there remains an element of surprise when equipment is opened and cleaned for inspection. In other words, the inspection of machinery and equipment parts which are not visible during normal operations may lead to unexpected changes to the work scope. The other characteristic is limited execution time. In order to minimize loss of production, turnarounds tend to have a very com-

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pact schedule of activities during turnaround execution such that the impact of any delay is magnified as the schedule may have higher critical activities. In order to prevent project delays and thus decrease project cost, it is in the best interest of organizations undertaking turnarounds to follow best practices of turnaround planning and management.

Power plant turnarounds have been identified as the most expensive and time-consuming of maintenance projects (McLay 2012). Trends in electrical energy production and demand indicate that the importance of following best practices in turnaround planning and management is likely to increase in future. A National Energy Board of Canada (NEB) report (National Energy Board of Canada 2013) showed that in 2012 electricity generation capacity in Canada reached 134GW and is projected to reach 164 GW by 2035. The NEB report further indicated that an average 1% increase in total electricity generation capacity in Canada is needed to meet growing demand, replace aging facilities, and to fulfill economic and environmental needs (National Energy Board of Canada 2013). In fact, rapid growth in global energy demand requires power plants worldwide to consistently run at near capacity. To keep up with these increasing demands for electrical energy, execution of turnaround projects will be subject to even tighter time constraints in future, making it all the more imperative that organizations implement whatever improvements they can and follow best practices for turnaround planning and management that have been shown to improve turnaround project performance. However, despite the considerable risk and growing constraints associated with turnaround projects, to date, there has been no comprehensive review of best practices for turnaround planning and management to which industry practitioners may refer.

This paper presents a comprehensive review of past research regarding the best practices to plan, manage, and execute power plant turnaround projects. Each best practice we recommend has been shown to improve performance in the previous research studies. Because delays and expanding work scopes are major contributors to turnaround project cost overruns, implementation of these performance-improving best practices will help lower turnaround costs. To help industry practitioners discern the extent to which the recommended best practices need or do not need to be implemented in their organizations, we further present a methodology for analysis of existing power plant turnaround planning and management processes. Using a case study, we illustrate the methodology by evaluating the level of implementation of best practices for turnaround planning and management necessary in a company based in Alberta, Canada. The company has several power plants in North America, and has a well-documented project management process used for turnarounds. In the case study, we compare the company's documented project management process to industry best practices for turnaround planning and management we obtained through our comprehensive literature review in order to identify any gaps in the company's existing practices. By identifying these gaps, we are able to highlight areas in which the company's practices should be revised in future. Our paper also provides recommendations for the improvement of some company practices for future turnarounds.

The contribution of this paper is in providing a comprehensive review of best practices for power plant turnaround planning and management and a systematic method of comparing a company's own documented practices against previously researched industry best practices so as to improve the planning and execution of future turnaround projects. The methodology can be implemented by other companies involved in turnaround projects in order to improve their own documented planning and management processes. Furthermore, future research can be done to compare a company's documented practices to its actual practices on turnaround projects to identify gaps between the theoretical and applied; in this way, researchers can evaluate the consistency of the application of a company's documented practices across turnaround projects.

2 RESEARCH METHODOLOGY

In construction, many industry standard best practices have been developed and are widely applied. These include best practices for project risk assessment, quality management, and front-end planning developed by the Construction Industry Institute (2014) (CII) and best practices for advanced work packaging and workface planning developed by the Construction Owners Association of Alberta (2014). However, there is a lack of industry standard best practices developed specifically for turnaround planning and management even though applicable best practices exist in published research literature. Industry practitioners were interested in implementing best practices to better their organization's performance of turnaround projects would benefit from a comprehensive review summarizing available literature on best practices relevant to turnaround planning and management; This paper provides such a review.

This paper includes two parts. In the first part, we perform a comprehensive review of best practices for turnaround planning and management. The literature review provides a collection of best practices from which all companies involved in turnaround projects can draw. While managers and engineers involved in turnaround planning and management will benefit from the recommendations provided by the literature review, it is also important to have a method capable of finding gaps in existing company practices for the purpose of process improvement. In the second part of this paper, we therefore provide a generic, systematic methodology that will enable any company that engages in turnaround projects to compare its existing, documented, company-specific practices with the published industry best practices we have reviewed. We demonstrate application of the systematic methodology using a case study. The challenge here is that best practices describe both general and detailed concepts for the planning and management of turnaround projects that have been compiled from various sources of published literature, whereas a company's own internal practices describe specific concepts particularly suited to company projects. Fayek and Peng (2013) faced a similar challenge when adapting industry standard procedures related to workface planning to organization-specific procedures. Their study focused on three different categories of procedures and practices: industry standard procedures and practices, organization-specific procedures and practices, and actual project practices (Fayek and Peng 2013). In order to overcome the difficulty of comparing two sets of documents which were written from two different perspectives, this paper proposes a methodology consisting of three steps: phase-to-phase comparison, comparison of each phase output, and missing best practices concepts. The steps of the proposed systematic methodology for comparing a company's own best practices against published best practices are illustrated in Figure 1.

Following this schematic, the first step is phase-to-phase comparison. This step compares consideration and timing of phases between the two sets of practices (internal/company-specific and industry/published). Without going into the detail of each phase's activity and outputs, the first step only provides an overview of how the case company's practices are similar to or different from industry best practices. After completing this step, a company following our comparison methodology will have a general idea of which recommended phases were not included in their own company's practices as well as which company practices phases are redundant based on the industry best practices. The timing of phases is compared so that a company may observe if it has planned some phases in a relaxed schedule with high buffers or if it has forced its phases into a compact and critical schedule.

The second step compares the output of each company phase to the related phases recommended by industry best practices. In our case study, both the case company practices and the best practices recommended by the literature we reviewed include details about tasks, task timings, and outputs of each phase. However, the industry best practices tend to focus more on the outputs. Therefore, in this step, for each phase all the required outputs are compared between the company's own practices and the best practices. In addition to the outputs of each phase, task timings are also compared. Upon completing this step, the gaps between a company's practices and the published industry best practices will be evident, giving companies following our methodology a starting point for improving their internal practices. We also demonstrate how to calculate the percent extent to which company practices diverge from best practices.

The third step deals with any best practices concepts that are altogether missing from the company's existing documented practices. As a result of the previous two steps, by this point all the company's documented practices have been compared to the best practices recommended by our literature review; however, there is always the possibility that one or more best practice(s) are entirely excluded from the company practices. Therefore, the third step re-examines the best practices we compiled and identifies those concepts and recommendations not covered by the company practices.

The proposed systematic methodology for comparison, in addition to the performed comprehensive review, will help all companies involved in turnaround projects identify areas of weakness in their planning

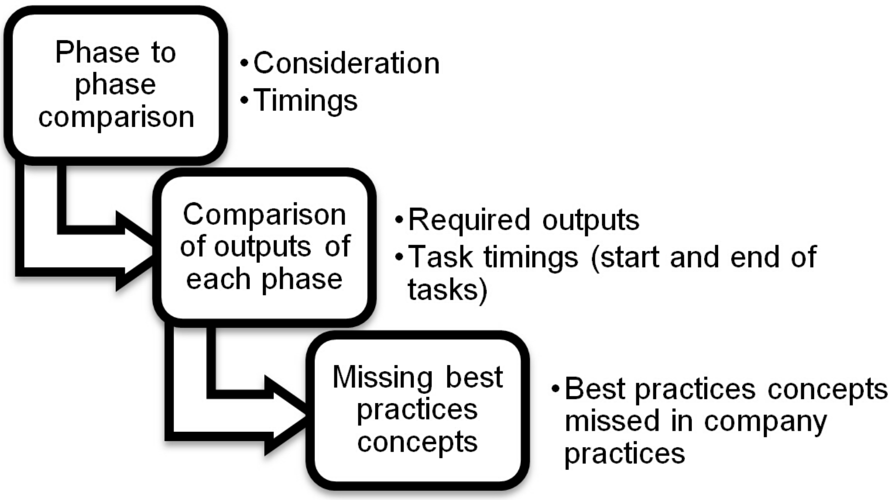

Figure 1. A systematic method for comparing company practices to published best practices

and management processes so that they can then address these issues to improve their practices.

3 BEST PRACTICES FOR POWER PLANT TURNAROUND PLANNING AND MANAGEMENT

This section outlines and presents a comprehensive documentation of past research that has been conducted regarding the best practices to plan, manage, and execute turnaround projects. It includes our recommendations based upon the conducted studies. Because they are based on proven best practices, implementation of the recommendations should improve power plant turnaround planning and management processes, leading to better project performance.

3.1 Planning of Turnaround Projects

To keep up with the shifting demands of the business environment, every work process must be fully integrated with a company's overall business plan. Work processes should also reflect the stage reached in the planning process, as needs change accordingly. Many turnaround practitioners believe that those work planning processes that begin immediately after completion of the last turnaround require considerably more effort and planning manpower than those that do not commence until nearer the actual turnaround dates (Oliver 2002), but this is not necessarily the case. If we assume that a given number of activities need to be accomplished through the planning process, in many cases it is actually more efficient to carry them out over a longer period of time than to expedite their completion closer to turnaround commencement. Nevertheless, a large portion of the scope of work remains unknown until right up to the beginning of turnaround management (Ertl 2004; Levitt 2004; Lenahan 1999; Oliver 2001; Oliver 2002) when the equipment is disassembled and examined.

A business that has developed a formal plant turnaround management process and procedure supported by plant turnaround management philosophy and long-term strategy will achieve a higher level of budget and schedule accuracy (McLay 2012). The plant turnaround philosophy should reflect the objectives of the corporate business plan. Developed according to these objectives, the plant turnaround management process includes the creation of a long-term strategic plan and the appointment a turnaround manager who will initiate the turnaround procedure.

Stages for turnaround projects

Oliver (2002) describes the different stages of the turnaround projects including required data, deliverables, and timing of each stage. Based on Oliver's description, turnaround stages include the business plan, conceptual development, work development, detailed planning, pre-turnaround work, turnaround execution, and post-turnaround stages.

Scope management and planning methodology

There are basically three categories of work scope in turnaround projects (Obiajunwa 2010), including known scope, anticipated scope, and emergent scope. Known scope includes work items that are well defined. Anticipated scope includes work items that are loosely defined, but based on estimates from inspections and other condition-based analytical results. Emergent scope includes work that emerges as the equipment is dismantled.

For both the known and anticipated scopes, Obiajunwa recommends a methodology for scope management in turnaround projects outlined by the Guide to the *Project Management Body of Knowledge (PMBOK Guide)* (Obiajunwa 2007; Obiajunwa 2010; Project Management Institute 2010). The recommended methodology includes four steps of scope identification: scope verification and validation, scope development, and scope planning. Firstly, scope identification should be performed by extensively studying past shutdown final reports, the computer maintenance management system database, operations and maintenance manuals, and documents relating to health, safety, and environment. Secondly, practitioners should complete scope verification and validation by completing inspections, determining which jobs should be completed during the turnaround, and then assessing these jobs to ensure that they can only be done during a plant shutdown. During pre-shutdown meetings for the validation and verification of the scope of work, each scope item should be verified and approved by the departmental heads. Thirdly, the scope development step should identify the details of the work scope which involves determining the exact tasks (job steps) for each work item. Practitioners should identify a work list for each job, determine the materials and spares needed, ascertain which equipment and tools are needed, and establish risk logs for major equipment components to track and monitor their condition. Finally, scope planning should be done as the final step in scope identification to properly define the known scope tasks or activities according to their duration, cost, and resource requirements. Anticipated scope should also be accounted for according to any technical or statistical information about the equipment obtained from available sources such as equipment maintenance history, evaluation reports on component condition of equipment from previous turnaround projects, non-destructive tests (NDTs), on-run inspections, and any other testing results.

In addition to known scope and anticipated scope, emergent scope should also be defined. Emergent scope is usually related work items that are not known prior to project execution and hence cannot be planned for in advance. Major sources of emergent scope include unanticipated scope, scope that is anticipated but under-estimated, and scope that is generated while carrying out the tasks. Turnaround management should plan to handle any emergent job items. Recommendations for managing the emergent scope include identifying an early scope freezing date, establishing an additional work procedure, and developing a management process for scope changes.

Risk Mitigation in Turnarounds

Risk mitigation is a crucial consideration for turnaround projects. Accordingly, practitioners should plan to minimize the amount of required work. The design review process and constructability reviews should both consider the risks posed by construction activities during the turnaround. The potential risks of completing excessive work during the turnaround increase project complexity and may result in increased costs, schedule delays, or in the worst case scenario, failure of the project to complete objectives. Planning and coordinating efforts during the pre-construction phases of the turnaround can help mitigate potential problems (Whittington and Gibson 2009). The CII presented some critical management issues that were identified as requiring additional care during turnaround planning (Construction Industry Institute 2008).

Cormier and Gillard (2009) stated that the implementation of a rigorous, structured knowledge transfer system can improve the success of any turnaround. Additionally, conveying appropriate process- and unit-specific information, specifications, and procedures to the multitude of parties involved in a turnaround can also reduce risk. Accordingly, Cormier and Gillard recommend communicating all of the specific tasks, schedules, priorities, contingencies, and perceived risks that should or might occur to each group of workers. The documentation, structure, and delivery of this information should be tailored to the destination audience while considering that any given group of workers may range widely in terms of craft, experience, and level of responsibility. To ensure these needs are met, the communication process should be verified. Implementing a rigorous, structured knowledge transfer system ensures that everyone involved in the turnaround follows a common set of best practices that can be refined over the years rather than relying on the combination of backgrounds, expertise, and biases of key players, who differ from one turnaround to the next. For instance, planning styles vary depending on the planner, and formal communication of the plan to all parties involved tends to relax as the event draws closer, leaving room for diverse interpretations. Furthermore, training for turnaround projects tends to be general in nature, casual in format, and dependent on the experience of the trainer. In other words, it is possible to have a good turnaround if the right people occupy leadership positions, but in other situations, an established knowledge transfer process crucially helps overcome disparate individual points of view (Cormier and Gillard 2009).

Reducing risks during the scoping phase of a power plant turnaround will improve the cost effectiveness of the installation (maintenance work). This risk reduction process combines improvements in the categories of organization, process, technique, and technology (Lazeroms 2011). These improvements will help reduce the level of risk related to installation during the scoping phase of a turnaround. Lazeroms (2011) stated that a significant portion of the total lifecycle costs of a power plant are accrued during the operational phase of an asset. Within the operational phase of a power plant, the majority of costs occur during a turnaround, and the actual cost of performed turnarounds usually exceeds the budget. Lazeroms (2011) provides insight into installation risks, the effects they have on operational decision-making during turnaround scoping, and methods and techniques for reducing these risks so as to improve cost effectiveness.

3.2 Turnaround Management Teams

It has been recognized that there is a need for multifunctional or interdisciplinary teams to handle the diverse activities of the turnaround planning process, and to ensure that the disparate requirements of all those who contribute to the turnaround are reflected in the final plan (Oliver 2002). Oliver (2002) recommends the following teams to manage the turnaround projects: the core team, steering committee team, and reviews or audits team. Firstly, a core team should be established to handle the planning process. Assembling this team is often considered as an end in itself, but really this is just the first step. Potential members should be assessed for their ability to work as part of a team and, where needed, appropriate training should be given. Not everyone is suited to being a team member in this context; this should not imply that such individuals are ineffective workers, but rather that their individual talents are best utilized outside a team environment (Duffuaa and Ben-Daya 2004; Duffuaa and Ben-Daya 2009). Secondly, the turnaround steering committee team should be established to provide direction and guidance to the core team and ensure that the turnaround meets the needs of the business. More importantly, the steering committee ensures that the scope aligns with the budget for the turnaround. The steering committee must regularly communicate with the core team to ensure the latter is kept informed of the work scope and current estimated costs of execution. Thirdly, in order to ensure that the planning and execution process is receiving appropriate attention and that progress is steady, a series of reviews or audits should be carried out at intervals throughout the process. The individuals conducting the audits should be appointed by the steering committee and should be knowledgeable in turnaround matters but should not have direct responsibilities in respect to the turnaround under review. It is desirable to include someone from outside the plant or organization for some, if not all, of the audits (Oliver 2002).

Other authors recommended creating an organizational unit within the plant operations division called the Plant Turnaround Services (PTS) department that is solely dedicated to managing the planning, preparation, and execution of the plant turnaround maintenance. With this organizational arrangement, all turnaround activities within the corporation are centralized and administered by PTS (Ghazali and Halib 2011). PTS is one of the functional departments in the plant operations division and is responsible for: (1) strategizing and developing turnaround maintenance operation plans for the company's plant turnaround maintenance activities; (2) managing and leading the preparation and implementation of the turnaround; (3) managing the material and service requirements of the turnaround; and (4) developing, implementing, and reviewing the turnaround's health, safety, and environmental protection (HSE) and quality control/assurance (QC/QA) plans and performance. Furthermore, Ghazali and Halib (2011) suggest an organizational structure for a turnaround project's execution team. The organizational structure consists of two main elements, namely, the resource structure at the bottom and the administrative structure at the top.

3.3 Turnaround Scheduling

Having a good strategy for turnaround scheduling will help practitioners develop a feasible schedule. A feasible schedule appropriately allocates resource units to jobs and provides temporally feasible job plans that respect given precedence constraints and working shifts. It is in an organization's best interest to minimize both the project's duration and its cost; however, there is a trade-off: fast project executions increase costs, whereas less expensive project executions take a long time. A balance needs to be struck.

Megow et al. (2011) developed and presented a two-phase approach for scheduling turnarounds. The first phase supports the project manager in finding a suitable project duration that respects his or her risk preferences, and the second phase optimizes the use of resources for the chosen duration. In the first phase, the strategic planning phase, the project manager must determine the turnaround project's start and finish dates (i.e., the makespan) as well as quantify the available workers and resources. In the second phase, the detailed planning phase, practitioners allocate and level resources for the heuristically determined deadline by completing a risk analysis of the computed, detailed schedule. This risk analysis should provide upper bounds for the risk measures "expected tardiness" and "probability of meeting the project duration" (Megow et al. 2011).

Determining a suitable project duration depends on several aspects that need to be balanced against each other. These include the total resource cost for hiring resource units, the total production loss caused by the shutdown during the turnaround period, and a "risk cost" due to unexpected repairs and delays that are inherent in maintenance jobs and tend to become more influential the shorter and more ambitious the project duration becomes. Elshout and Garcia (2009) stated that shutdown plans have to be well organized so that all the work dovetails within the allotted shutdown period. They suggest that when developing the schedule, to maintain flexibility, the activities should be broken down into a large number of steps, each of which has an early start date and last-possible completion date. The objective is to pre-install and complete as much of the construction as possible in advance of the shutdown. Because shutdown time is very limited, only tasks that absolutely must be done during the unit shutdown are undertaken at this time. This approach also allows for fewer people onsite during the critical period of shutdown activities. Elshout and Garcia (2009) suggest that before developing a high level of schedule detail, practitioners may use a simpler bar chart-type schedule to chart the timings for ordering long-lead-time equipment such as thick-walled reactors, alloy equipment, and high-pressure vessels. Working back from the desired start of work in the field, the project manager can determine the latest time at which an order can be placed. Ordering requires some lead time during which necessary pre-purchasing activities can be completed. Sometimes, equipment purchases must be made before the final design is completed.

3.4 Turnaround Management

There are some general practices in managing turnaround which should be followed to better overcome turnaround challenges. Duffy and Tregoe (2012) define the top challenges and critical areas in managing turnaround projects. Ensuring workforce safety of both employees and contractors is the number one priority for the turnaround management team. Other challenges and critical areas include the development, deployment, and communication of an effective turnaround process; managing project scope creep during the turnaround execution; the capture, analysis, and availability of relevant information and metrics; the existence of business processes which do not support the needs of the turnaround; cost management and control in executing complex turnarounds; the coordination and management of complex resources; the transformation of an organization from reactive to proactive; and managing the expectations of diverse stakeholders. In order to overcome turnaround managing challenges the following areas should be considered during the planning, management, and execution of turnaround projects: development, deployment, and communication of an effective turnaround process; capture, analysis, and availability of relevant information and metrics; overcoming business processes which do not support the needs of the turnaround; coordination and management of complex resources; overcoming a reactive culture by moving toward anticipating and resolving issues before they impact; and managing the expectations of diverse stakeholders (Duffy and Tregoe 2012).

Synchronizing turnaround project execution can improve turnaround performance impressively. (Gupta 2011) suggested the use of critical chain project management (CCPM) to coordinate priorities during turnaround execution because it enables managers to synchronize work items despite uncertainties related to engineering, planning, and execution. To synchronize project execution, CCPM prescribes three rules: pipelining, buffering, and buffer management. The first rule is pipelining, which limits the number of work streams in execution so as to avoid spreading resources too thinly and causing bottlenecks, local prioritization, and unsynchronized work. The second rule is buffering, which discards local schedules and measurements and uses an aggregate buffer to protect projects from uncertainties. This approach favours the final project deadline over task deadlines. The third rule is buffer management. Following this rule, practitioners focus efforts on task prioritization instead of creating detailed and rigid plans, as such exactitude may result in conflicting priorities. By closely monitoring the rate of project buffer consumption, practitioners can quickly spot which tasks are consuming buffer most quickly and can then adjust resources to support tasks most likely to cause the biggest delays in project completion (Gupta 2011). The results of this methodology are impressive. Gupta (2011) cites several examples, including a Spanish nuclear power plant that by using buffer management succeeded in increasing its due date performance by 35% (to 95%) and its throughput by 30%, and another European nuclear plant that dramatically increased its due date performance to 90% and its throughput by 25% for pre-shutdown engineering activities.

Scope change management (SCM) should also be conducted for turnarounds. Al-Qadda (2009) has conducted research regarding scope change in petrochemical plant turnarounds. He recommended that SCM should follow a change procedure that consists of activities such as change request initiation, change request review, evaluation of change request, and change request approval. The addition, modification, or deletion of scope can all prompt the initiation of a change request. Further to following the change procedure for turnaround there are two other important issues that should be considered as part of SCM. Firstly, practitioners should take care to minimize the changes in the turnaround scope of work. Al-Qadda (2009) has presented the following recommendation for how to do so:

i The original scope must be clearly and properly defined;
ii Plant equipment failures and defects that arise between the scope sign off and the execution time must be recorded immediately for immediate and necessary action;
iii Historical information, including that related to each completed turnaround, must be documented so that it can be referenced in future;
iv A suitable strategy for accepting scope changes must be adopted so that the number of scope changes can be minimized;
v Action must be taken to appropriately address turnaround scope objectives with the intent of reducing scope changes on future turnaround projects; and
vi A proper database system to store historical data should be constructed as it will be useful in reducing the scope changes.

Secondly, practitioners should minimize the impact of changes on safety, duration, cost, and quality. Al-Qadda (2009) also presented the following recommendations minimizing the impact of changes on safety, duration, cost, and quality:

i Scope changes that arise at later stages must be attended to immediately or, if possible, deferred to the next turnaround so that present turnaround duration is not affected;
ii Practitioners should devote enough time to developing turnaround scope so as to minimize the possibility of scope changes at later stages;
iii If a change can be accommodated immediately, it must be completed and not deferred so that turnaround quality is not affected; and
iv All alternative methods of performing scope changes must be investigated, and in each situation the alternative with the lowest cost must be applied.

One potential strategy for reducing the time it takes to process scope change requests is to create predefined formats that can be quickly and easily approved. To reduce the impact of work scope changes on the turnaround process, a suitable combination of these SCM principles and a company's existing change management principles should be adopted.

4 CASE STUDY ANALYSIS OF AN ACTUAL POWER PLANT TURNAROUND PLANNING AND MANAGEMENT PROCESS

We conducted a case study in order to help provide recommendations for improving a certain company's project management processes for turnaround projects. The company in question is active in the energy sector with several coal and gas power plants in Alberta, Canada. The case study compares and contrasts the best practices for power plant turnaround planning and management derived from the literature review in Section 3 of this paper (referred to from hereon in as "best practices" or "BP") to the company's existing, documented standards for managing its turnaround projects (referred to from hereon in as "company practices" or "CP"). The presented case study follows the steps described in the methodology in order to better illustrate how the proposed methodology can be applied by companies involved in turnaround projects. The main objective in conducting this comparison is to point out the similarities and differences between the two sets of practices so as to identify any gaps in the company's existing standards.

It is important to consider that BP describes both general and detailed concepts for the planning and management of turnaround projects that have been compiled from various sources of published literature, while CP describes practices intended for a specific company project management team. Therefore, CP tend not to highlight more general concepts; instead, they focus on the outputs of each phase, templates used, and the responsible persons. In order to compare CP with BP, we follow the methodology shown in Figure 1. Accordingly, in the first step, we introduce and compare the different phases suggested by BP and CP. Next, we compare the activities and outputs of each CP phase with related aspects of BP. In the third step, we identify the BP recommendations excluded by CP.

4.1 Phase-to-Phase Comparison

Our proposed methodology stipulates that the systematic comparison should begin by comparing the CP turnaround phases to those recommended by BP. The BP divide turnaround planning and management into phases that are part of five-year plans. In CP, turnaround phases are described in detail for a period beginning about two years prior to breaker open (the Project Execution sub-phase start time) and ending about four months after breaker closed (the end of the Project Execution sub-phase). The beginning and end of the turnaround management phases described by CP and BP are different in some cases. Furthermore, the BP describe some phases for which there are no matches in CP and vice versa. Figure 2 illustrates the comparison of turnaround phases defined by BP to the phases defined in CP. As shown in Figure 2, this phase of the comparison shows two major gaps between BP and CP. One gap relates to the definition of phases. According to CP, the project management team should commence work by about two years before a turnaround project and should finish turnaround-related work four months after breaker closed. However, the BP consider turnaround planning and management in a more general sense, calling for five-year plans for each turnaround. Such a five-year plan may include ongoing business processes and turnaround-specific processes. The other gap relates to the timing of phases. In CP, each phase is scheduled to start only after the previous phase has been completed, and there are no gaps in time between phases. In BP, however, in some cases a time interval between phases exists. Accordingly, it can be inferred that these time intervals can include work related to ongoing processes and can also accommodate possible delays.

Other companies involved in turnaround projects can apply the first step of our proposed methodology to their own context. Although the CP will differ from one company to another, this step is generic and will give any company a better perspective of how their practices are similar or different to BP.

4.2 Comparison of Outputs and Task Timings of Each Phase

According to our proposed methodology, in the second step, practitioners should compare outputs of each CP phase with related aspects of BP in order to find gaps and commonalities between the two sets of practices. Furthermore, they should also compare the start and end times of activities in each turnaround phase detailed by CP with those prescribed by BP. It is important to note that the comparison carried out in the second step of the proposed methodology is more detailed than that in the first step, and the results achieved are therefore very specific. Because of this difference in level of detail, companies should still complete the second step of our methodology even if the comparison in the first step showed that the CP were well aligned with BP, as there still is a possibility of finding significant gaps between phase outputs and the timings of phase activities between the two sets of practices. For this case study, we performed a detailed comparison of outputs and task timings; Table 1 shows part of this comparison and provides details regarding each phase's major outputs and their timings. Note that the blank spaces in the table are related to items documented in one set of practices that have no direct parallels in the other. Findings will of course vary for different companies applying our methodology; however, the level of detail discussed here shows how specific the second step of the comparison should be. Our intention is to help potential users of our methodology visualize what benefits they can anticipate from this step.

Providing a detailed comparison similar to what presented in Table 1 for all activities will help reveal gaps in the outputs and task timings of each CP phase. Experienced managers and engineers can use a document like this one to help improve turnaround planning and management processes; as they know by experience the

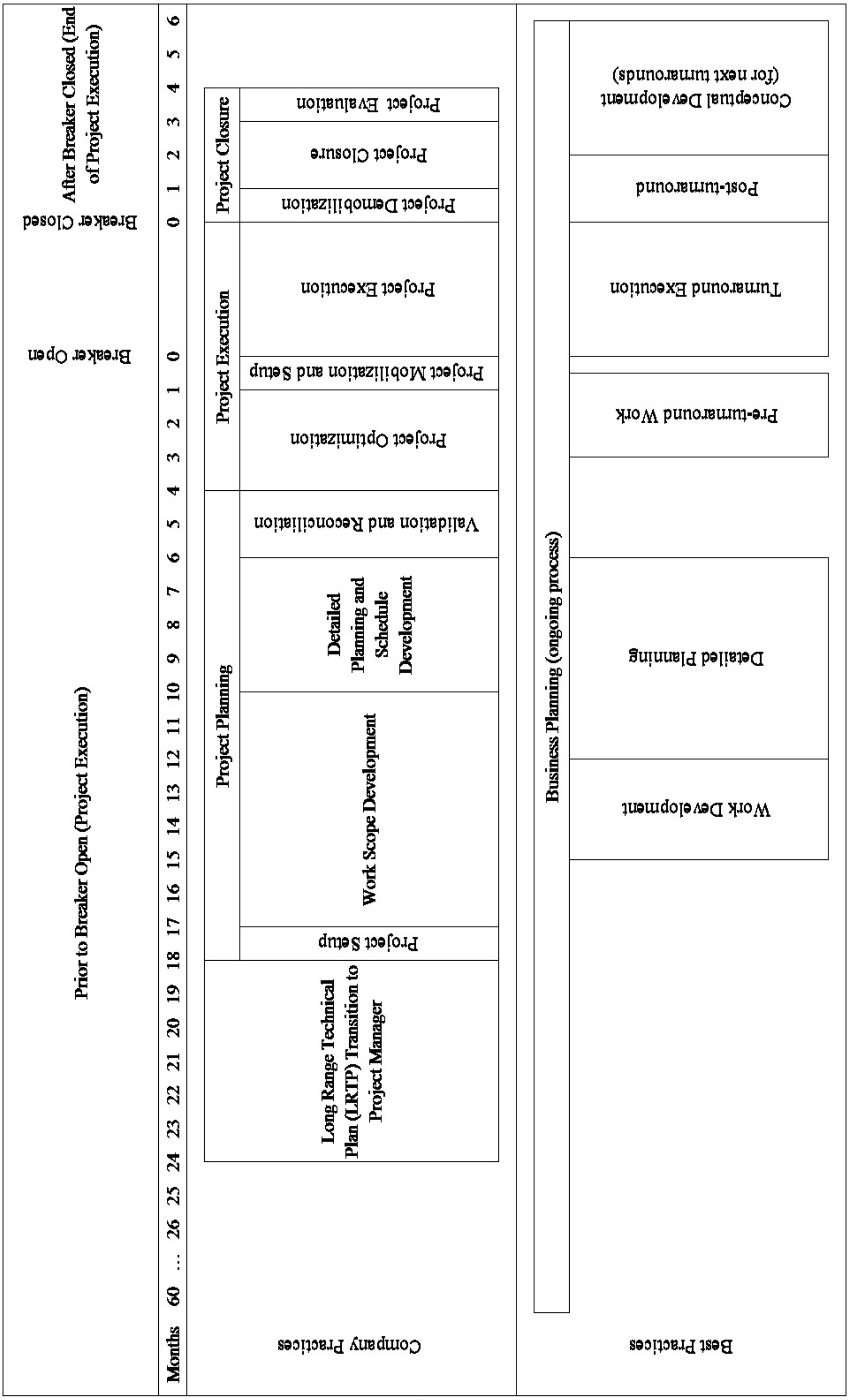

Figure 2. Comparison of company practices to best practices phases

Table 1. Sample comparison of outputs and task timings of select phases

Phase		Output		Start		End	
Company Practices	Best Practices	Company Practices	Best Practices	Company Practices	Best Practices	Company Practices	Best Practices
Work Scope Development	Work Development	Engineering scope document	Preliminary and approved work list	17 months to Breaker Open	15 months prior to turnaround	10 months to Breaker Open	12 months prior to turnaround
Work Scope Development	Work Development	Updated financial forecast	Refined budget estimate (both expenses and capital)	17 months to Breaker Open	15 months prior to turnaround	10 months to Breaker Open	12 months prior to turnaround
Work Scope Development	Work Development	Updated long lead procurement list	Long lead materials ordered	17 months to Breaker Open	15 months prior to turnaround	10 months to Breaker Open	12 months prior to turnaround
Detailed Planning and Schedule Development	Detailed Planning	Integrated baseline schedule	Integrated execution plan	10 months to Breaker Open		6 months to Breaker Open	6 months prior to turnaround
Detailed Planning and Schedule Development	Work Development	Preliminary resource plan	Integrated plan (schedule, equipment, and resources)	10 months to Breaker Open	15 months prior to turnaround	6 months to Breaker Open	12 months prior to turnaround

criticality of an output or its related activities compared to other outputs, they can decide which outputs to target for process improvement first and then improve company processes systematically by trying to decrease gaps they observe in their own, complete version of Table 1. In addition to reducing the gaps in existing outputs, process improvement may also include the addition of outputs recommended by BP but non-existent in current CP. A document like Table 1 can also compare how CP and BP differ in timing of tasks related to outputs. For these reasons, drawing up a comparison chart like Table 1 is a useful visualization exercise for turnaround practitioners as they decide which changes they should make to their planning and management processes (e.g., changes in resources, altering of team composition) in order to bring their CP into line with BP. Using this tool, companies following our methodology can choose to implement the necessary changes as immediately or gradually.

Our case study illustrates the implementation of this step in our methodology. The BP consider some phases for turnaround planning and management that, as shown in Figure 2, overlap with several phases of the CP. Thus, it is possible for an output required by a given BP phase to either exist for the same (parallel) CP phase, exist for another (non-parallel) CP phase, or not to exist for any CP phase. For the purposes of this exercise, the first state is of interest, the second state is considered a deviation that should be corrected, and the third state indicates a gap that should be filled. Here, we describe the findings of our case comparison and categorize them into these three categories following the BP phases.

Business Planning Phase

In this study, the CP did not include the Business Planning phase at all; however, they did specify some required outputs related to business planning in other phases. Out of 9 BP outputs related to business planning, 5 did not exist in CP, and one was considered in another phase of CP.

Work Development Phase

The CP Project Setup sub-phase and CP Work Scope Development sub-phase are parallel to the BP Work Development phase. Out of 17 outputs in the BP Work Development phase, only 1 did not exist in CP, and 3 were considered in another phase of CP.

Detailed Planning Phase

The CP Detailed Planning and Schedule Development sub-phase and the Validation and Reconciliation sub-phase are parallel to the BP Detailed Planning phase. The detailed comparison of outputs showed that out of 9 outputs required by the BP Detailed Planning phase only 1 did not exist in CP.

Pre-Turnaround Work Phase

The CP Project Optimization sub-phase and the Project Mobilization and Setup sub-phase are parallel to the BP Pre-Turnaround Work phase. Out of 10 outputs required by the BP Detailed Planning phase, only 2 did not exist in CP.

Turnaround Execution Phase

The CP Project Execution sub-phase is parallel to the BP Turnaround Execution sub-phase. For this phase, the CP and BP outputs match.

Post-Turnaround Phase

The CP Project Demobilization sub-phase and Project Closure sub-phase are parallel the BP Post-Turnaround phase. Out of 13 outputs in the BP Post-Turnaround phase, only 1 did not exist in CP, and 1 was considered in another phase of CP.

Conceptual Development Phase

CP considered outputs related to the BP Conceptual Development phase in the Project Execution sub-phase and Project Set-up sub-phase with some major omissions. Out of 17 outputs in the BP Conceptual Development phase, 5 did not exist in CP. Table 2 summarizes the comparison of BP and CP phase outputs. Deviations are outputs considered by CP in different phases than recommended by BP whereas gaps are outputs absent from CP that are required by BP.

One way to present the results of this comparison is to list them by item. For example, a gap may be presented as “BP recommend forecasting the turnaround budget for the next five years as part of the business plan, but CP do not consider five-year forecasts in the turnaround budget”. Similarly, a deviation may be presented as “While BP recommend that long lead material purchase orders are finalized in the Work Development phase, CP specify that vendor contracts are to be signed in the Project Optimization phase”. Earlier in this section, we presented all the deviations and gaps we found by comparing CP to BP. While it may be useful for engineers involved in turnaround projects to know the item-wise details of this comparison, presenting the results to turnaround managers will be more effective as an illustration of overall trends. For example, for our case study we compiled the deviations and gaps discussed above and displayed them in a bar chart (Figure 3).

Figure 3 reveals the percentages of deviations and gaps identified from the comparison of CP to BP. It can be observed from Figure 3 that there is no deviation or gap between CP and BP during the Turnaround Execution phase. However, when it comes to the BP Business Plan and Conceptual Development phases, the gaps between the two sets of practices are more than 50% (55.6% and 62.5% respectively). The chart also shows that overall, the deviation between the two sets of practices is 6.8% and the gap between CP and BP is 20.3%. Illustrating the results of this comparative analysis as we do in Figure 3 makes it easy for turnaround managers to perceive which phases have more deviations and gaps and thus require more process improvement attention.

4.3 Missing Best Practices Concepts

In the third step of the proposed methodology, the major BP concepts and items that should be included in CP in future should be discussed. As we demonstrated, in the previous two steps, CP and BP are compared and discrepancies between the two sets of practices are identified and presented so as to highlight areas for

Table 2. Summary of phase output comparisons between best practices and company practices

Phase	Total No. of Outputs	No. of Deviations	No. of Gaps
Business Plan	9	1	5
Work Development	17	3	1
Detailed Planning	9	0	1
Pre-turnaround Work	10	0	2
Turnaround Execution	8	0	0
Post-turnaround	13	1	1
Conceptual Development	8	0	5
Overall	74	5	15

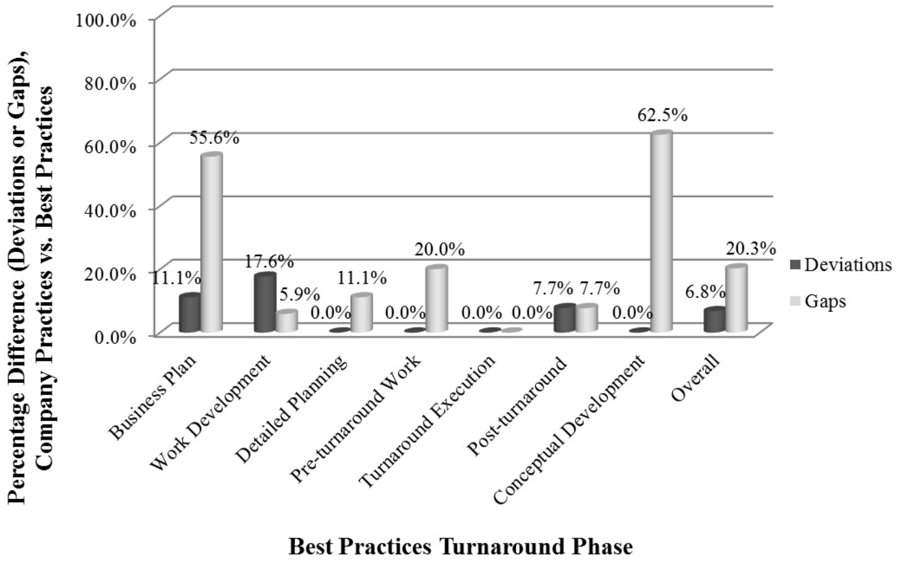

Figure 3. Overall comparison of deviations and gaps (company practices versus best practices)

future improvement of company's existing turnaround project practices. However, some BP concepts may be altogether omitted from corresponding sections of CP.

For example, the concept of team building was discussed in our Section 3.2 review of BP where we defined characteristics of turnaround management teams according to existing BP literature. The BP include team building in the Pre-Turnaround Work phase and define the different teams involved in turnaround management. Inclusion of a turnaround management organizational chart in CP may aid management personnel in establishing and structuring teams. However, while team building is a major concept discussed in the BP, many companies may, as did the case study company, exclude this concept from their documented planning and management processes since in many cases, company personnel will have worked together for a long time already and their teams will have been gradually shaped over time. In these cases, from one turnaround to the next, the need for including team building in the Pre-turnaround Work phase or elsewhere in the turnaround planning and management process is significantly reduced.

Another BP concept that was entirely omitted from the CP we examined in our case study is risk mitigation. In BP literature, sources of uncertainty during the scoping phase are divided into four categories: organization, process, technique, and information. For each category, sources of uncertainty are presented. In order to reduce the risk associated with a power plant turnaround, BP suggest reducing risk by making improvements under each category. BP literature insists on the importance of following this practice for mitigating risks to ensure turnaround success; however, turnaround practitioners may diverge from this practice by differently categorizing risks, providing insufficiently detailed information for risk mitigation, or, as in our case study, considering risk mitigation outside of the scope of turnaround planning and management specifically. Consecutive turnarounds occurring at the same specific plant will require many similar activities, and considering the fact that turnaround planners and managers responsible for a plant may work numerous turnaround projects at that same plant, risks associated with turnarounds may be identified over time. For this reason, the need for an explicit risk mitigation process during each turnaround may be somewhat diminished. While risk mitigation is practiced by the case study company, the associated internal policies and procedures do not appear in the CP for turnaround planning and management.

These two missing best practices concepts or any of the other major concepts discussed in Section 3 of this paper may well be overlooked by a company where our methodology is applied. Highlighting these missing concepts is crucial future process improvement, which is why this third and final step in our methodology must be performed in addition to the previous two.

5 CONCLUSIONS AND RECOMMENDATIONS

The contribution of this paper is in providing a comprehensive review of best practices for power plant turnaround planning and management and a systematic method of comparing a company's own best practices against documented best practices, which can help a company improve the planning and execution of its turnaround projects. We reviewed past research regarding the best practices to plan and manage turnaround projects and provided guidelines and recommendations based on these best practices. Previous research failed to provide a comprehensive review of best practices for the planning and management of turnaround projects even though the need for such a review has only been increasing. We also presented a methodology for the analysis of company-specific power plant turnaround planning and management processes in relation to those recommended by best practices; this methodology can be implemented by companies involved in turnaround projects. We illustrated our methodology using a case study wherein we compared the existing documented practices of an actual company with the best practices we discovered through the literature review. Our analysis identified similarities and differences between the company practices and the best practices, and focused on finding gaps between these two sets of practices. Our analysis of the identified deviations and gaps between the company practices and best practices will assist the case company's management team as they work to improve their practices in future. If managed properly, integrating previously absent best practices and re-scheduling differently scheduled practices to bring them into line with best practices will lead to the process improvement of turnaround planning and management. Implementation of the recommendations and guidelines provided in this paper by managers and engineers involved in turnarounds is expected to contribute significantly to better performance, fewer possibilities of cost overruns, and less significant time delays in future turnaround projects. The methodology we propose can be implemented by any company involved in turnaround projects in order to improve existing, documented, company-specific turnaround planning and management processes. Because it helps identify deviations and gaps at both higher levels (e.g., turnaround phases, missing best practices concepts) and lower levels (e.g., phase outputs) of the turnaround planning and management process, our methodology provides a powerful foundation on which to base the process improvement of turnaround planning and management processes.

This paper used documented company practices for the basis of our comparison with best practices. In future, this research can be extended to compare a company's documented practices to its actual, implemented practices on turnaround projects to identify gaps between the intended and followed practices so that it would be possible to examine how consistently documented practices are applied across turnaround projects.

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REFERENCES

Al-Qadda, M. S. (2009). *Sabic Plant Shutdowns and Turnarounds, Scope Variation Practical Approach*. M.Sc. Thesis, Open University Malaysia, Kuala Lumpur, Malaysia.

Construction Industry Institute (2008). *Front End Planning of Renovation and Revamp*. Projects Implementation Resource 242-2, Construction Industry Institute, Austin, Texas, United States.

Construction Industry Institute (2014). *CII best practices (Project risk assessment, Quality management, and Front end planning)*. Construction Industry Institute. Available at <https://www.construction-institute.org/> (accessed 08/02/2014).

Construction Owners Association of Alberta (2014). *Advanced Work Packaging & Workface Planning*. Construction Owners Association of Alberta. Available at <http://www.coaa.ab.ca/> (accessed 08/27/2014).

Cormier, B. and Gillard, C. F. (2009). "Beyond turnaround planning." *Petroleum Technology Quarterly*, Q1, Available at <http://www.eptq.com/> (accessed 08/27/2014).

Duffuaa, S. and Ben-Daya, M. (2009). *Handbook of Maintenance Management and Engineering*. Springer, London, United Kingdom, Chapter Turnaround maintenance.

Duffuaa, S. O. and Ben-Daya, M. (2004). "Turnaround maintenance in petrochemical industry: Practices and suggested improvements." *Journal of Quality in Maintenance Engineering*, 10(3), 184–190.

Duffy, K. and Tregoe, K. (2012). "Strategies to optimize shutdowns, turnarounds and outages." *Reliable Plant* Available at <http://www.reliableplant.com/> (accessed 01/20/2013).

Elshout, R. and Garcia, D. (2009). "Strategies for a smooth turnaround." *Journal of Chemical Engineering*, 116(7), 34–39.

Ertl, B. (2004). *Applying PMBOK to Shutdowns, Turnarounds and Outages*. Plant Maintenance Resource Center. Available at <http://www.plant-maintenance.com/> (accessed 09/10/2014).

Fayek, A. R. and Peng, J. (2013). "Adaptation of workface planning for construction contexts." *Canadian Journal of Civil Engineering*, 40(10), 980–987.

Ghazali, Z. and Halib, M. (2011). "Towards an alternative organizational structure for plant turnaround maintenance: An experience of PETRONAS Gas Berhad, Malaysia." *European Journal of Social Sciences*, 25(3), 40–48.

Gupta, S. (2011). "Completing turnaround projects faster with full scope." *Electric Light and Power*, 89(2), 36–39.

Lazeroms, H. (2011). *Reducing Risks in the Scoping Phase of a Power Plant Turnaround will Improve the Cost Effectiveness of the Installation*. MSc Thesis, Asset Management Control Centre Academy, International Masters School, Den Helder, Netherlands.

Lenahan, T. (1999). *Turnaround Management*. Butterworth Heinemann, Oxford, United Kingdom.

Levitt, J. (2004). *Managing Maintenance Shutdowns and Outages*. Industrial Press Inc., New York, New York, United States.

McLay, J. A. (2012). *Practical Management for Plant Turnarounds*. JMC Consulting Ltd., Edmonton, Alberta, Canada.

Megow, N., Möhring, R. H., and Schulz, J. (2011). "Decision support and optimization in shutdown and turnaround scheduling." *INFORMS Journal on Computing*, 23(2), 189–204.

National Energy Board of Canada (2013). *Canada's Energy Future 2013: Energy Supply and Demand to 2035*. Available at <http://www.neb-one.gc.ca/> (accessed 07/21/2014).

Obiajunwa, C. (2007). "Optimization of turnaround maintenance project implementation." *ARCOM Doctoral Workshop: Facilities, Refurbishment and Maintenance Management*, Sheffield Hallam University, Sheffield, United Kingdom.

Obiajunwa, C. (2010). *A Framework for the Successful Implementation of Turnaround Maintenance Projects*. PhD Thesis, Sheffield Hallam University, Sheffield, United Kingdom.

Oliver, R. (2001). "Organising the plan for turnarounds." *Petroleum Technology Quarterly*, Q3, Available at <http://www.eptq.com/> (accessed 08/26/2014).

Oliver, R. (2002). "Complete planning for maintenance turnarounds will ensure success." *Oil and Gas Journal*, 54–62.

Project Management Institute (2010). *A Guide to the Project Management Body of Knowledge (PMBOK Guide)*. Project Management Institute, Newtown

Square, Pennsylvania, United States.
Whittington, D. and Gibson, E. (2009). "Development of the STAR tool for the management of shutdown/turnaround/outage projects." *Building a Sustainable Future: Proceedings of the Construction Research Congress*, 685–694.