Project Management-Related Delays and Mitigations to Power Generation Planned Turbine Maintenance Outages

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Abstract

This research determines and mitigates project management delays during turbine maintenance outages. Such mitigations would benefit the organisation in improving plant availability and increasing electricity availability to the consumers through load shedding reduction. The research was triggered by turbine maintenance outages which override the targeted contractual date due to deficiencies in the implementation of project management philosophies and controls. The scope of this research begins at the outage planning phase and ends when the machine returns to service. This study formulates a list of project management delays and mitigation strategies for the said delays to achieve project objectives. It further arrives at conclusions that are directed at the power generation industry and maintenance industries in general.

Keywords
Project management delays, mitigation strategies, turbine maintenance outages.

1. Introduction
The South African power generation industry has been faced with unreliable power production efficiencies which limit the availability of constant electrical energy to the South African grid for the past decade (Goldberg 2015). The instability of electrical power availability not only affects the consumers but also weakens the country's economy with Gross Domestic Product (GDP) statistics as a result of high prices, low market product exchange and investments (Gonese et al. 2019). Electricity generation and supply shortages result in the country's national control implementing planned rolling blackouts, referred to as rotational load shedding (Goldberg 2015). Various factors that are a threat to the national grid integrity are said to be: delayed planned and unplanned outages; high planned and unplanned capacity load factors (including distribution and transmission); high daily load losses; deficiencies in maintenance and lack of effective management and leadership performance (Holtzhausen 2012). In addition to the threats mentioned, one of the highlighted impacts of the shortage of electricity and increase in cost is turbine outages that take longer than planned to come online (Eskom 2017).

Power generation turbine maintenance philosophies operate in such a way that machines are shut down at certain manufacturer-recommended intervals to allow machine inspection and where necessary refurbishment to be done. The primary purpose of planned maintenance practice is to maximize reliability by restoring a plant or equipment to optimal condition and minimizing operating costs (Rezaei 2017). Tabucanon and Dahanayaka (1989) also maintain that planned shutdowns are aimed to increase equipment performance which results in lower operating costs.

It is the responsibility of the project manager to oversee the project from initiation until closure, and his main accountability is to manage the triple constraints (Abu-hussein et al. 2016). These constraints are to deliver a project on time, within budget and to the desired scope, not ignoring the safety aspects (Sommerville et al. 2013). Mtembi and Kanakana (2016) state that project management activities during the project cycle are the project managers' responsibility but are not limited to planning, organising, controlling, directing, forecasting, developing staff, motivating, communicating and coordinating. This paper examines and presents project management delays in planned turbine maintenance outages. These delays are then subjected to mitigation strategies to eliminate the delays.

2. Literature Review

Project management is widely known to be a time-limited, focused and non-repetitive task (Sepehri 2006). Its cycle tends to follow similar patterns. Therefore, delays and mitigation strategies developed through literature and research as a whole would apply to a wide range of industrial technical projects. The project management gaps identified should be mitigated to reduce delays (Kesavan et al. 2015). See the depiction in Figure 1.

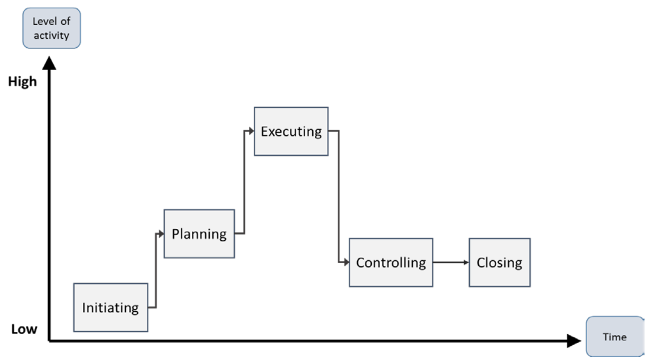

Figure 1. (Maintenance) Project Management Life Cycle (Mtembi and Kanakana 2016)

2.1 Turbine Definition and Maintenance Process

A steam turbine is defined as a steam-driven rotary engine system that consists of components such as valves, blades, casings, rotors, pumps and bearings. The principle is that the superheated steam energy from the boiler enters into the high-pressure turbine through the steam admission pipes, and safety and control valves to rotate the turbine rotor. As the turbine rotor rotates it then drives an electric generator as they are coupled together as a unit (Juneja and Wadhwa 2016). The rotary motion of the generator rotor then creates a magnetic flux between itself and the generator stator which produces electricity through the bushing chamber into the transformer (Runwal 2017). The steam turbine is deemed the main thermal facility in a power generation plant, and its flow and sequence of activities during maintenance overhaul is exceptionally multifaceted, thus exposed to slipups (Wang and Ma 2008). Owing to the criticality of turbine operation and maintenance, it is consequently vital that planned maintenance outages of turbines are executed by skilled personnel to meet the triple project constraints defined as time, cost and scope, (Juneja and Wadhwa 2016). In addition, an organisation's intellectual knowledge and strategy assessment for tactical operations such as turbine operations and maintenance is valuable (Merizalde et al. 2019).

Turbine components are subjected to extreme conditions and are certain to deteriorate during long-term operation due to wear and tear (Sao et al. 2014). It is recommended that a suitable maintenance plan has to be made to extend the lifetime of the turbine and its auxiliaries (Enomoto 2016). This is a maintenance system where specified maintenance checks are carried out at planned strategic intervals to retain optimal operation levels, and prevent catastrophic failure and high repair costs. Turbines as the heart of the power generation process also undergo this planned maintenance at specified intervals (running hours) as recommended by the manufacturers to ensure higher reliability (Juneja and Wadhwa 2016). The challenge is to execute and deliver this planned maintenance efficiently and avoid overriding the specified contracted due date owing to project delay influences. Figure 2 represents a comprehensive steam turbine maintenance plan process over its life cycle, and how planned maintenance outages fit into the whole philosophy.

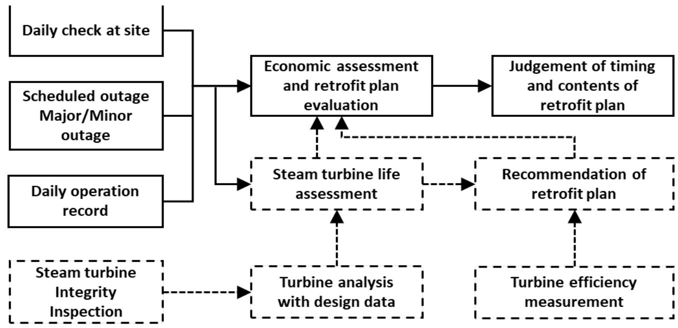

Figure 2. Turbine Maintenance Plan Procedure (Enomoto 2016)

2.2 Management and Technical Team Roles

The project manager is a critical resource for any project as his managerial and leadership roles towards the project team and stakeholders have a direct influence on the project's success (Anantatmula 2010). The project manager's accountability has been defined as planning, leading and supporting project teams, monitoring project progress, and ensuring that all project activities are completed satisfactorily to ensure stakeholder satisfaction (Kerzner 2009). Additional project manager roles are motivating team members, driving problem-solving initiatives, providing project tools and direction, defining each member's role and competence, encouraging open and effective communication, and creating a trusting environment (Anantatmula 2010). In turbine maintenance outages, the project manager also has a responsibility to ensure before the outage begins that the scope is frozen on time, the tender is presented and project order number is given, subcontractor orders are issued and process quality plans are developed and approved. The shortcomings in project management roles will contribute to an outage overriding its due date.

Project outcomes are subjected to among others the scope, which sets project boundaries and influences project duration, risk and cost. The project scope creation and modification are among the functions of the project technical team, mostly the engineering department (Zwikael and Smyrk 2011). Therefore, one of the major roles of technical/engineering resources in a project is to support the project to ensure that scope is delivered at a specified quality and standard. Trevelyan (2007) researched the technical coordination in engineering practice which outlined the functions of the engineers in the technical field. The research states that the roles support that of a project manager as they also cover engineering planning, providing engineering expertise, resolving technical challenges, hands-on work during execution to ensure quality, supervision and delegation of technical work, monitoring technical work, reviewing and developing standard procedures (Trevelyan 2007). The lack of focus and attention to the stated functions will contribute to due dates not being met, in addition, to rework which has the potential to increase the project cost. Any technical delays in addition to project management delays are the accountability of the technical team which feeds into project management drivers.

2.3 Technical and Project Management Delays

Risk assessment is a fundamental part of the risk management process. It is thus understood that proper project risk assessment during the planning and continuously in the execution stage will bear positive project results. Consequently, a poor project risk assessment generally becomes one of the project delay contributors (Grant et al. 2006). Project delays are understood by Sepehri (2006) to be contributed to by organisational and personal causes, with little effect as a result of environmental factors. Organisational causes are a lack of proper project management application coupled with training.

A project delay case study was conducted by Tabucanon and Dahanayaka (1989) at the power plant. During the overhaul project, two issues were highlighted during execution concerning the bar chart scheduling method that was used to manage the turbine outage project. It was found that: (a) actual task durations took longer than planned due to plant deterioration levels and unexpected faults, and (b) resources could not be assigned to cover all the planned tasks.
Furthermore, factors that have been identified to affect project success are planning, risk management, quality management and barriers to project implementation, stakeholder management and communication (Mtembi and Kanakana 2016). The factor that could significantly contribute to the project delay during the disassembly and assembly

activities is work sequencing. It is thus important to arrange work schedules to accommodate critical manpower and material resources and align them with demand time (Wang and Ma 2008).

Deterioration elevates the levels of risk, which eventually lead to a high possibility of scope changes during the project execution as the opportunity required for maintaining the plant is not offered (Hlophe and Visser 2018). A study conducted by Mhlanga et al. (2017), on delays in maintenance projects found that the causes were related to poor communication during planning and execution among the project stakeholders. This included purchasing and delivery of the required material. The scope change and work quality were other major contributors to delays if the risk assessment is not conducted during the planning stage to address the unknowns. Eizakshiri et al. (2015) and Soliman (2017) agree with the theory that project delays are not solely the product of the project management team or technical mistakes as has been repeatedly proclaimed in academic research for years. Delays can generally come from the plan itself which is in most cases being computed by a stand-alone department. When establishing the cause of the delay, its effect and consequences, it is important to consider that project a plan is presented in a perfect future and mostly ignores the known unknowns (Eizakshiri et al. 2015). Injecting significant overtime hours on a project to accelerate it has also been proven to have a negative effect, thus causing delays in the project through quality decline. This is because resources tend to develop burnout effects (Estate et al. 2000). Figure 3 provides a summary of planned turbine maintenance outage delays from the literature.

Project risk management

- Lack of risk management (identification and application) causes delays as more surprises are realised as the project progresses. Project risk management is inclusive of scope change risks, quality risks, project cost and time delay risks.

Project management knowledge and implementation

- Lack of project management tools and techniques knowledge from project team contributes to delays as individual efforts will not be in harmony. The role of a project manager covers the facilitation of coordination between team members to focus on the common goal and drive similar objectives. Misalignment of project team members with project tools used to drive and monitor the project contributes to progress delays through misaligned reporting.

Project plan management

- Poor project plan management results in a mismatch between the plan and activity schedule. This can be contributed by poor time estimates, plant deterioration levels or resource inefficiency. Work sequencing, time management and resource allocation to tasks is part of the project plan management that the project manager has to look at as it negatively affects the project due date.

Stakeholder engagement and communication

- Lack of communications results in project interfaces with other departments being poorly managed and causes delays and an increase in waiting time. The delay also can emanate from the end goal being shifted unintentionally during the project execution due to lack of engagement and communication with project owners.

Project quality management

- Reworks or repetitive tasks are not planned for and thus delays the project plan. Rework contributes to delays as tasks have to be repeatedly done which affects planning and scheduling since the resources will not be available to continue with the next activities. This time delay factor is counted under quality which both engineering and management accounts for.

Project scope management

- Scope extension results in due date extension and cost escalation and subsequent mismanagement contributes to project delays. Scope variations (increments) are commonly approved by senior management since it impacts on the project due date and well as project cost.

Figure 3. Planned Turbine Maintenance Outage Delays Summary

2.4 Mitigations to Project Management Delays

The cost of a maintenance project is linked to the schedule which means that as the schedule slips the cost escalates. Mitigations have to be implemented by employees to avoid project slips. Therefore, it is emphasised that the plan should incorporate the known unknowns other than trying to squeeze a good project into a distorted plan (Ellen et al. 2015). It is also recommended that to eliminate power utility outage delays, project management training and exposure should be extended not only to project managers but to all the stakeholders physically involved in projects (Mtembi and Kanakana 2016). Concurrent technical skills training should be rolled out (in the form of energy-related courses) at all personnel levels to build capacity and for all involved to understand the effect of scope adherence and the impact of shortcuts (Hlophe and Visser 2018). Partnership prospects with Original Equipment Manufacturers (OEMs) also have been promoted to alleviate quality issues, planning and knowledge sharing (skill transfer) (Mtembi and Kanakana 2016). Furthermore, one of the delay factors identified is the result of poor communication between project parties. It is recommended that poor communication should be avoided by informing all involved levels of the project objectives, obstacles and risk mitigations (Mhlanga et al. 2017). The involvement of critical stakeholders during the project definition is also recommended to mitigate scope deviations and a shortage of resources in case of scope changes (Mhlanga et al. 2017)..

Maintenance outage projects for complex operations adopt the form of turnaround maintenance (TAM), which is a periodic total shutdown of the plant to reduce unscheduled breakdowns (Pokharel and Jiao 2008). Managing maintenance of turbine overhauls is known to involve multiple interdependent project activities which together form what is known as a project plan. The common conventional project management tools such as Gantt charts, Critical Path Method (CPM) and Program Evaluation and Review Techniques (PERT) are repeatedly applied when planning outage projects (Jonsson 2015). Although the said tools can integrate both dependent and independent tasks, they fall short in analysing dependency between tasks or the information flow among activities. To overcome this limitation, it is recommended to utilise the Dependency Structure Matrix (DSM). DSM is defined as a square matrix that comprises a visual representation of a system or project network representing dependencies. It offers a transparent view of multiple interconnected activities for a process and highlights what information is a prerequisite to begin an activity. It manages task relations for complex projects through task sequencing and iterations (Browning 2016).

Project risk management

- Project manager should involve critical stakeholders when drafting the risk assessment and mitigation factors.
- Risk assessment should be kept and managed as a live document through the project, from project definition to closure.
- Risk management plan to be acknowledged by senior project stakeholders for adoption
- All subcontractors to formulate and submit risk assessment and mitigation plans to the project manager for acceptance

Project management knowledge and implementation

- Project management training and exposure should be extended not only to project managers but to all the stakeholders physically involved in projects for project goals alignment.
- Visual progress display should be utilized that all team members are aligned with the day-to-day project objectives.
- Individual team member key performance areas to be agreed on and signed prior the project commencement.

Management of project plan

- Project scheduling, including planning matrix must ensure that resource bottlenecking is avoided during the project execution through resource levelling techniques.
- Use of Dependency Structure Matrix (DSM) other than the traditional Gantt charts, Critical Path Method (CPM) and Programme Evaluation and Review Technique (PERT).
- Monitoring of performance and efficiency throughout the project stages.
- Project plan to be updated and revised continuously to align with progress and due date.

Stakeholder engagement and communication

- Lack of communications results in project interfaces with other departments being poorly managed and causes delays and increase in waiting time. The delay also can emanate from the end goal being shifted unintentionally during the project execution due to lack of engagement and communication with project owners.

Project quality management

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Figure 4. Planned Turbine Maintenance Outage Delays Mitigations Summary

Garon and Garon (2013) place more emphasis on incorporating lessons learned from previous projects to be carried over to the new project and future projects for continuous improvement. The stakeholder management and communication element ensure that all critical spares are procured on time and subcontractor orders are released timeously to improve the turbine maintenance project management and meet the specified project success criteria (Mtembi and Kanakana 2016). Figure 4 provides a summary of planned turbine maintenance outage delay mitigation from the literature.

3. Methods

The overall design strategy for this research was an interview study methodology that followed a qualitative approach to capture and analyse information on delays from recently planned turbine maintenance outages. It is common with qualitative research to make use of interviews to obtain thick, rich data based on a qualitative investigational perspective (Turner 2010). A standardised open-ended questionnaire was used to gain an understanding of participants' experiences and in-depth information regarding project management delays and mitigations during planned maintenance outages (Turner 2010). The choice of research methodology is said to be established by considering the nature and features of the research problem, as well as solutions to be established (Jamshed 2014).

The questionnaires were used while conducting interviews with senior project managers, project managers, and project engineers of the South African energy industry based on their interest and involvement in planned turbine maintenance outages. Questions were constructed to respond to issues such as quality management, risk management, stakeholder engagement, scope management, resource scheduling and team members' training as listed by the literature. The alignment of research questions with interview questions were conducted to intensify the effectiveness of interview data outcomes in the research process while eliminating unnecessary discussions.

The interview recordings were transcribed and sent to each participant for verification, with the final validated script sent back to the researcher by the interviewee for data analysis. After all the meanings were assessed for causes of project management delays, similarities were turned into un-predetermined themes using text analysis. The themes were derived from responses other than predefined themes. Data triangulation was conducted using data formed from the literature review and data collected through individual research interviews. This triangulation compared the results as data nodes established during the literature review and themes categorised during the interview analysis, the alignment was established.

4. Results and Discussion

Power generation turbine maintenance outage delays do not only emanate from the execution of work itself. They originate right from the project planning phase and build up till the end of the project. The present research intended to identify and mitigate project management delays during turbine maintenance outages. The results of the research are summarised in Figures 5 and 6.

Research revealed several themes of project management delays that directly affect project deliverables. It included project plan management, and project management knowledge and implementation as the dominant delay themes. Compliance with planning and disciplined execution, ascertaining that project constraints and drivers meet stakeholder expectations and critical on-time delivery was also identified. Project spares management processes have to be proactively defined before the execution phase as a plan to eliminate late mobilisation and procurement delays. Poor project management was discovered to be an umbrella to poorly formulated and executed plans, poor leadership strategies and decisions, and poor management of project processes. These themes directly implicate the project leadership resources, mostly the project manager's leadership character and ability to optimise the resources at his disposal.

Technical and project management factors that contribute to planned turbine maintenance outage delays

There are similarities between technical and project management factors. The project management factors revealed by both literature and interviews of the study were as follows; unavailability of spares, poor project planning, lack of execution skills, late mobilisation, poor leadership, lack of processes and procedures, poor project management, lack of quality control, management corruption, lack of training and coaching, lack of stakeholder engagement and communication, poor project scope management and poor project risk management.

Figure 5. Planned Turbine Maintenance Outage Delays Findings

The mitigation strategies to reduce project management delays to planned turbine maintenance outages

The results from both literature and interviews highlight the following as the mitigation strategies: project pre-planning, use of DSM computer programme, daily scope management with milestone tracking, defining and implementing processes that will aid in inferior quality reduction, introduction on engineering intervention and hold points, use of Six Sigma and Lean principles, use of training matrix to equip the resources with training and implementation of new technology advancements, partnering with the original equipment manufacturers to gain technical knowledge, promoting team training and upskilling which involves all the stakeholders, holding individuals accountable with performance measurement, skills retainment, succession planning and forming technology core teams, project progress information display to enable access to all the stakeholders to easily check project progress.

Figure 6. Mitigation Strategies to Planned Turbine Maintenance Outage Delays

As project risk management runs from project inception to close out, poorly managed risks tend to invade a well-managed task and delay the entire project, especially when the delays fall in the critical path. Risks may lead to scope creeps, thus there is a link between risk management and scope management that the entire team should work on to mitigate such potential project management delays. Training and coaching not only address the skills issue but cover quality and focus on day-to-day milestones which spread out to the whole project schedule. The technical knowledge depth of the project manager, gained through training and practical experience enables him to see the warning signs before extensive non-compliance with the schedule materializes. Using a suitable training matrix that addresses skills and development at large was revealed as a vital tool for consideration and adoption.

This research identified the benefits of using continuous improvement tools through Lean and Six Sigma methodologies. These methodologies provide error-proofing benefits and technological advancement options to ensure quality compliance with the benefits being eliminated on rework delays. Quality-related matters can also be addressed through partnerships with OEMs with skills transfer as the added benefit. Investing in critical skills has been identified as one of the mitigation factors to project management delays. This can be done through the development and implementation of succession planning processes, skills retention policies and the development of specific machine technology core teams. Once these processes are implemented and training conducted, individual performance management has to be implemented to hold the team accountable. It was found that there is no fine line between technical and management delays. They overlap and are listed for similarity – thus the research covered both. Mitigations to the delays could be well formulated from the literature and interviews. Future research is recommended in the field of management corruption mitigations as well as to draw a line between technical and management delays in projects.

5. Recommendations

The following recommendations are presented based on the information gathered during this research.

- Adherence to pre-planning and continuous day-to-day activity schedule tracking should be adopted by organisations involved in maintenance projects to review resource loading, resource dependencies, required special tools for the tasks and spares availability.
- The energy generation industry should invest in training and development to ensure that turbine maintenance outages are executed to a high-quality standard. These outages are defined as complex, thus to be executed by competent resources with an in-depth understanding of risks and consequences.
- Future research is recommended to discover in-depth knowledge regarding management corruption delays in power generation turbine maintenance outages to stop such acts.
- It is recommended that future research which covers the same topic should shy away from using pre-set questions for interview protocols as they limit specific follow-up questions that would link each mitigation with its specific delay during the interview.

6. Conclusion

This research aimed to determine and mitigate project management-related delays to planned power generation turbine maintenance outages. Based on a qualitative analysis of literature and through interviews during the study, it can be concluded that there is a wide spread of project management delays that affects the project due dates in power generation turbine maintenance outages. Such delays negatively impact on electrical power availability to the national grid. Mitigation strategies formulated through this research have to be followed to reduce the unreliability of power supply due to planned turbine maintenance outages that override the targeted contractual dates.

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