# Delay Analysis in Energy Utility Maintenance Project

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## Abstract

During operation in the coal-fired power plant, the cyclic operation of the plant exposes components and systems such as boilers to high pressure and temperature, resulting in mechanical and thermal fatigue damage. Like most engineered systems, maintenance of these boilers is required to improve the availability and safety of the plant. However, delays are common in the execution of these maintenance projects. This study explored factors contributing to delays and their effects on boiler maintenance during half station shut down in a coal-fired plant. The study adopted a qualitative approach using project documents and open-end questionnaires as a data source. The findings identified sixteen factors contributing to delays, and twelve effects thereof. Additionally, mitigation for dealing with contributing factors is also presented. The study results can assist practitioners working in boiler maintenance to adopt a proactive approach to manage delays and contributes to the global field of knowledge.

## Keywords
Boiler, delays, effects, maintenance and mitigation

## 1. Introduction

Coal-fired power plants are energy converter systems and primary electricity generators in South Africa and globally. Water under pressure is converted into steam through heat generated by the combustion of pulverized coal as fuel. Steam is expanded through a turbine to produce mechanical power. The mechanical power in the turbines rotates the generator rotor to produce electrical power (Babcock and Wilcox Company 2005). During operation, systems and components of the coal-fired power plant such as boilers are exposed to high pressure and temperature resulting in wear and fatigue of tubes and other components, thus adversely affecting the efficiency of the plant and reducing its design lifetime. Like most engineered systems, to improve the conditions indicated above, availability and safety of the plant, maintenance of these boilers are important to minimise breakdowns and to avoid expensive plant shutdowns.

A coal-fired power plant owned and operated by an energy generating company in South Africa embarked on boiler maintenance commonly known as half station shutdown (HSD) from October 2017, with a planned completion date of March 2018. The HSD is a preventive maintenance philosophy adopted by the energy generating company to improve plant reliability. The HSD involved performing maintenance on half of the total boiler units in a power plant in parallel. For example, if a power plant consists of six boiler units, maintenance is performed on three of the six boiler units simultaneously. The scope of work of the HSD included replacement and repair of systems such as boiler pressure part systems, high-pressure piping and burners with the objective of preventing the development of risky operating conditions, optimize operation and energy efficiency. Due to the nature of work, it is important that delays during the execution are minimised, and that boiler units on maintenance return to service as scheduled to reduce the burden on the national grid (Van der Nest 2015). However, the completion of the maintenance was faced with several challenges. A significant challenge faced during this maintenance execution is delays. These delays emanated from various sources, resulting in maintenance contractors resorting to strategies such as recruitment of additional manpower, requesting time extension and extending working hours as remedies in attempt to meet schedule obligations. These practices prove to be not only costly but ineffective, as the project resulted in a calculated overrun of two months.

A case study was conducted to find factors contributing to delays and their associated effects in boiler preventive maintenance (HSD) in a coal-fired power plant in South Africa, focusing on boiler scope. By identifying these factors, the boiler engineering maintenance company can adopt a proactive approach to deal with factors contributing to delays. The results of this case study are not declared as general for all the coal-fired power plant projects in South Africa or anywhere else in the world but remain specific to the power plant understudy.

## 2. Literature Review

"A project is a temporary endeavour undertaken to create a unique product, service, or result" (PMBoK 2013:4) with the objective to fulfil a client's need. Performance, cost and time are significant components in a project, and these three elements are the critical project management factors (Larson and Gray 2018). These factors from project management are outlined by the iron triangle in Figure 1 which demonstrates the relationship between scope, cost and time.

The inclusion of a time component in the trade-offs is an indication that the completion time of a project forms part of the evaluation measures for success in projects. When a project does not meet its expected completion date, it is said to be delayed and failed to meet one of its direct objectives. Delay is defined in the context of a project as an extension of time on agreed project completion time between parties involved in the project time (Seboru 2015; Atout 2016).

Despite the application of numerous techniques including project management tools, delays remain a significant challenge and globally scholars recognised the challenges faced in delivering projects on time (Vaardini and Subramanian 2015; Atout 2016; Sadkowska 2016).

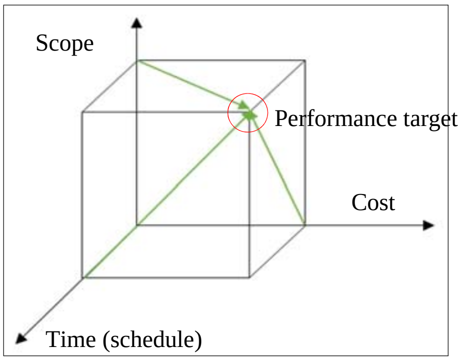


Figure 1. Project management direct project goals

Vaardini and Subramanian (2015) suggested that the fact a project is a process is therefore subjected to several dynamics, and this makes it difficult to correctly predict delays which can emerge from variable sources. The statement by Vaardini and Subramanian (2015) is further confirmed by Haji-Kazemi et al. (2015) who indicated that project activities are interrelated, project delays occur because project tasks or activities are linked, and have both external and internal cause and effects relation.

### 2.1 Delay Categories and Factors Grouping

Project delays are classified into three categories, namely non-excusable, excusable and concurrent (Kustamar and Putranto 2017; Ntoyanto 2017; Zarei et al. 2018). A non-excusable delay is generally acknowledged as delay caused by the contractor. The contractor is responsible for the delay hence the contractor is not eligible for an extension of time or remuneration (Keane and Caletka 2015).

Excusable delay consists of two classes; namely, compensable and non-compensable. Keane and Caletka (2015) described excusable compensable delays as delays that originate from the actions that are outside of the contractor's control however inside the owner's control. Having an excusable compensable delay warrants the contractor to an extension of time and financial recovery.

The excusable non-compensable delay is triggered by occurrences outside the ability to control by both the project owner and the contractor (Kustamar and Putranto 2017). According to Keane and Caletka (2015), an excusable non-compensable delay is the result of actions for which neither the owner nor the contractor is responsible. Examples include force majeure, severe climate conditions, and industrial strikes. This kind of delay permits an extension of time to the contractor to complete the work.

Concurrent delays are distinct delays to the critical path method. This delay is caused by the simultaneous occurrence of excusable and non-excusable (Kustamar and Putranto 2017). Ntoyanto (2017) added that this delay is the reason for disputes between project stakeholders.

In addition to the above categories, many researchers group and categorised delay factors differently (Aziz and Abdel-Hakam 2016). Zarei, Sharifi and Chaghouee (2018) summarised delay factors into five categories in accordance with the PMBoK's five processes of project management: delay factors related to initiation, planning, executing, controlling and closing processes. Freeman (2016:17) confirmed that "there is no agreed theory for determining the association between categories and concepts.

## 2.2 Factors Contributing to Delays

There has been extensive writing regarding factors contributing to delays across various industries (Owolabi et al. 2014; Gebrehiwet and Luo 2017; Callegari et al. 2018; Zidane and Andersen 2018). Zidane and Andersen (2018) highlighted the key role of construction delays in Norway, and the findings rank inadequate planning, scheduling, and indecisiveness by project stakeholders as main factors leading to delays. Chiu and Lai (2017) in Hong Kong identified insufficient labour, late decision making by client and scarcity of competent contractors and workforce as the top leading delay factors in a major construction project. Kustamar and Putranto (2017) covered several factors pertaining to delays in Indonesia. The study revealed that poor workmanship, human resources, geographical conditions, late approval of drawing and change, labour strikes, and changes in the scope to be the leading factors contributing to delays in road maintenance projects. Findings by Durdyev et al. (2017) in Cambodia indicated material shortage due to late delivery, impractical project duration, unskilled labour force, project complexity and absenteeism by workforce as dominant factors causing delays residential construction projects. A study in Iran by Samarghandi et al. (2016) attributed delay factors into four categories: owner defects, contractor defects, consultant defects and law, regulation and other general defects. Fallahnejad (2013) similarly studied causes of delay in the oil, gas and petrochemical pipeline projects in Iran, and identified inadequate monitoring, inadequate planning and scheduling, incorrect allocation of resources to be the main factors affecting timely delivery of projects.

Mofokeng and Marnewick (2017) conducted a case study in an aircraft maintenance company to establish causes of delays during A-check maintenance. Poor planning, unplanned breakdowns and ineffective logistics processes among others are the causes of delays. Research by Magadagela et al. (2017) analysed factors that affect trains efficiency in a South African's leading freight company, the findings pointed crew shortage, insufficient coordination of resources, locomotive imbalance, and noncompliance of train plans as factors contributing to high dwell times of cargo trains.

Table 1 presents additional factors adding to delays in projects, as cited by different researchers globally. Studies presented in Table 1 have lists of factors contributing to delays, the quantity of which varies from ten to hundred, factors presented are the main factors.

Table 1. Factors contributing to delays

| Findings/factors causing delays | Source |
|---|---|
| Deficiencies in initial negotiations | Zarei et al. (2018) |
| Procurement of materials | Kaliba et al. (2009), Amandin and Kule (2016), Gebrehiwet and Luo (2017) |
| Inaccurate budgeting and resources | Samarghandi et al. (2016) |
| Errors in design | Alsharif and Karatas (2016) |
| Ineffective communication | Hsu et al. (2017), Khan and Gul (2017), Zidane and Andersen (2018) |
| Lack of information exchange between stakeholders | Van et al. (2015) |
| Lack of commitment to the project by stakeholders | Taherdoost and Keshavarzsaleh (2016) |
| Unclear requirement and continuous change to requirements. | Da Silva and Ferreira (2015), Montequin et al. (2016) |
| Inadequate risk management. | Haji-Kazemi et al. (2015) |
| Quality management and monitoring challenges. | Aiyetan et al. (2012), Haji-Kazemi et al. (2015) |
| Recruitment difficulties | Kaliba et al. (2009 |
| Lack of review and corrective action | Zarei et al. (2018) |
| Project stakeholders' inexperience | Islam et al. (2015), Aziz and Abdel-Hakam (2016), Hsu et al. (2017) |

| | |
|---|---|
| Low productivity by the workforce | Gunduz and AbuHassan (2017) |
| Poor project management | Islam et al. (2015) |
| inadequate project control and management | Mpofu et al. (2016) |
| Lack of support from senior management | Alsharif and Karatas (2016) |
| Excessive workload and working hours | Islam et al. (2015) |
| Errors during the execution phase of the plan | Ntoyanto (2017), Callegari et al. (2018) |

## 2.3 Effects of Delays

Delays have direct and indirect effects on projects. The extent of effect(s) differs extensively from one project to another (Sadkowska 2016; Durdyev et al. 2017). Amandin and Kule (2016) suggested that a relationship exists between delay and cost. Sunjka and Jacob (2013) stated that as time increases, costs increase, pointing to the financial implications of delays. Niazi and Painting (2017) reported that delays are the main contributor to cost overruns. Furthermore, Aziz and Abdel-Hakam (2016) claimed that there is an inverse proportionality between the project value and time. Project value reduces as delivery time is extended. This claim is confirmed by Awojobi and Jenkins (2016), and Vaardini and Subramanian (2015), whose findings indicated that delays inflate project costs and reduce benefits.

The study on effects of delays by Mukuka et al. (2015) identified increased in cost, loss of revenue, dispute, poor workmanship due to pressure to complete the project, stress to project owner and contractor, idling workforce, and claims are among the significant effects of delays. These findings of Mukuka are similar to those of Sunjka and Jacob (2013) and Owolabi et al. (2014). Mofokeng and Marnewick (2017) quantified the increased in cost caused by delays in aircraft maintenance and the value amounted to approximately 10.8 million US Dollars. Khair et al. (2017) suggested that these increases in project costs may include legal costs due to disputes and litigation. Ntoyanto (2017) argued that the effects of delays are not limited to financial implications, delays may jeopardise project feasibility, stakeholder confidence in the project and sometimes cause slow growth. Depending on the severity; delays may lead to the abandonment of the project (Mukuka et al. 2016). Table 2 presents a summary of the effects of delays identified in the literature.

Table 2. Overview of the effects of delays

| **Effects of delays** | **Researcher** |
|---|---|
| Time-overrun | Sunjka and Jacob (2013), Amandin and Kule (2016), Mukuka et al. (2016) |
| Poor workmanship | Mukuka et al. (2016), Malekela et al. (2017) |
| Increased in project cost | Mukuka et al. (2016), Khair et al. (2017), Niazi and Painting (2017) |
| Loses revenue by the project owner | Alzara et al. (2016), Mukuka et al. (2016) |
| Reduced project value | Aziz and Abdel-Hakam (2016), Malekela et al. (2017), Ntoyanto (2017) |
| Safety risks | Vaardini and Subramanian (2015) |
| Stress on the workforce, Idling workforce, dispute, Contractor bad reputation | Mukuka et al. (2016) |
| Adversary relationship between the contractor and the project owner | Aziz and Abdel-Hakam (2016) |
| Unhappy client | Aziz and Abdel-Hakam (2016) |
| Project cancellation or termination | Mukuka et al. (2016) |

### 2.4 Mitigating Delays in Projects

There is ample literature on factors causing delays; however, few suggestions for possible interventions for dealing with factors contributing to delays. Zidane and Andersen (2018) listed several remedies to deal with factors contributing to delays, including improved resource allocation, interdisciplinary coordination and executive support. According to Kaliba et al. (2009), strike and unrest can be resolved through suitable and effective legitimate resolution processes. Kustamar and Putranto (2017) suggested empowerment of the communities around the project to take part effectively. Khair et al. (2017) claimed that the selection of an experienced and competent project manager with relevant knowledge of the project can minimise the likelihood of delays. Many scholars recommended that more effort should go to planning, scheduling and cost evaluation to assess the risks of possible delay (Haji-Kazemi et al. 2015; Al-Hazim et al. 2017; Chiu and Lai 2017; Niazi and Painting 2017). Among other mitigations, effective communication, motivation and team collaboration are suggested (Niazi and Painting 2017). Hwang et al. (2013) suggested investing in the training of the workforce and knowledge transfer to deal with factors such as a shortage of human resources and incompetence.

Literature indicates that there are no universal root causes of delays hence there are no universal solutions for specific delay factors. This highlights the uniqueness of projects as echoed by other researchers (Doraisamy et al. 2015; Montequin et al.2016; Zidane and Andersen 2018). The interpretation is that there is no one size fits all solution for delays in projects.

## 3. Research Methodology and Design

This study adopted a qualitative approach to answer the research questions due to its flexibility and less requirement on sample size than quantitative research approach (Creswell 2014; Blumberg et al. 2014; Saunders et al. 2016; Sekaran and Bougie 2016). A case study strategy was adopted as the research focused on identifying factors contributing to delays and their effects in a specific plant. Project documents consisting of project schedule risks registers, resource plan registers and early warning records were used as secondary data. Project documents were reviewed, and contents were analysed to draw delay factors. Primary data was collected through open-ended questions, allowing the participants the flexibility to answer in the free text. Electronic mails were employed to distribute and collect feedback because power plants are production environments and it was not practical to conduct individual or focus group interviews at the time of the study. Sekaran and Bougie (2016) confirmed that there is significant variability in the collection of qualitative data. Zidane and Andersen (2018) also collected qualitative data in their study of delays in the Norwegian project using open-ended questionnaires.

The targeted population is specific, and only individuals who were directly involved in boiler maintenance were selected. The selection was based on respondents' roles and experience in boiler maintenance in the coal-fired power plant. A total of twenty-one people from different competency areas in the engineering field were considered as research sample. Blumberg et al. (2014) confirmed that there is no agreed sample size in a qualitative study. This sample included three construction quality controllers, two construction managers, two construction supervisors, one design engineers, three project managers, one planner, one quantity surveyor, two resident engineers, two risks management personnel, one systems engineer, two welding engineers and one welding coordinator from both the client and the main contractor. Seventeen completed responses were received. Figure 2 and Figure 3 show the profile of research participants.

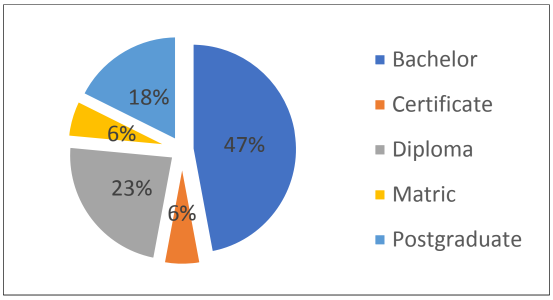


Figure 2.Participants qualification

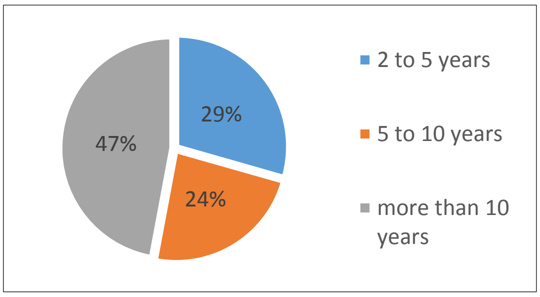


Figure 3. Participant experience

The data gathered were analysed using open coding and sorted according to their frequency. Validation of the findings was achieved through triangulation of different source of data, including literature, project documents and participant responses (Sekaran and Bougie 2016).

## 4. Research Results

### 4.1. Factors Contributing to Delays

The analysis of project documents revealed that recruitment difficulties of human resources, strike and unrest by the locals and workforce, low productivity by the workforce, poor workmanship and changes in scope are the contributing factors to delays.

Participant feedback presented sixteen main factors contributing to delays as illustrated in Figure 4, namely strike and unrest, changes in scope, inadequate planning, recruitment difficulties, inadequate competent workforce, scarcity of skilled workforce, inadequate supervision, project complexity, poor workmanship, ineffective communication, material and equipment , errors in design, unrealistic project duration, quality management and monitoring challenges, inadequate coordination of resources and emergency breakdowns.

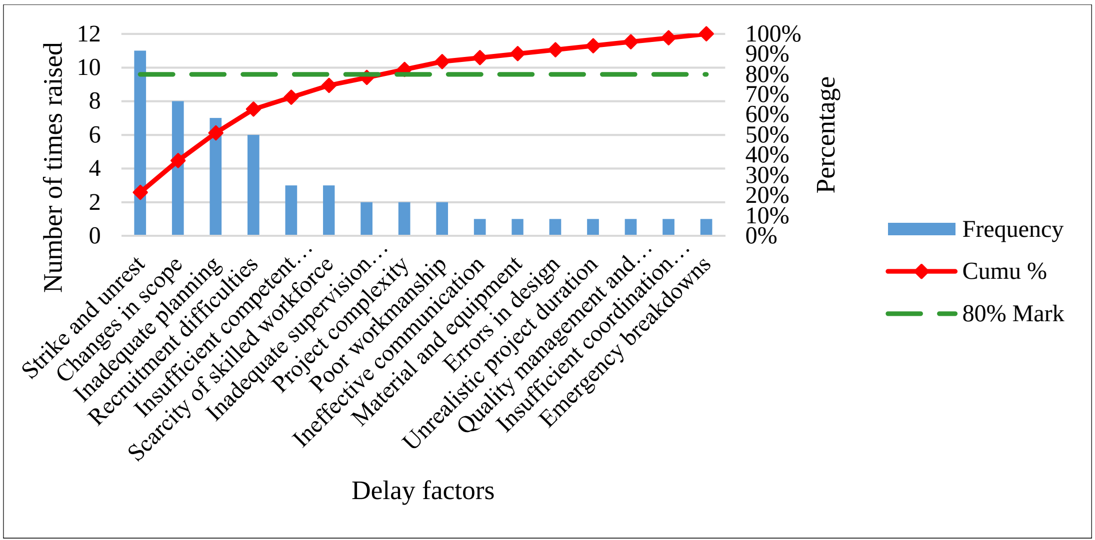


Figure 4. Pareto chart of main factors causing delays

The Pareto chart illustrated in Figure 4 differentiates the factors with the most contribution to delays based on their frequency. The top twenty percent of delay factors comprises strike and unrest, changes in scope, inadequate planning and scheduling, recruitment difficulties, insufficient competent workforce, scarcity of skilled workforce and inadequate supervision and resource allocation are grouped in accordance with the five PMBoK's standard processes according to grouping derived by Zarei et al. (2018) as presented Figure 5. The grouping that are identified with the PMBoK's standard processes are: initiation, planning, executing and monitoring and control processes. Figure 5 indicates further that delays in the half station shut down occurs mostly in the planning and monitoring and control processes. Figure 6 confirms that forty-eight percent of the top twenty percent of delay factors are related to the planning process.

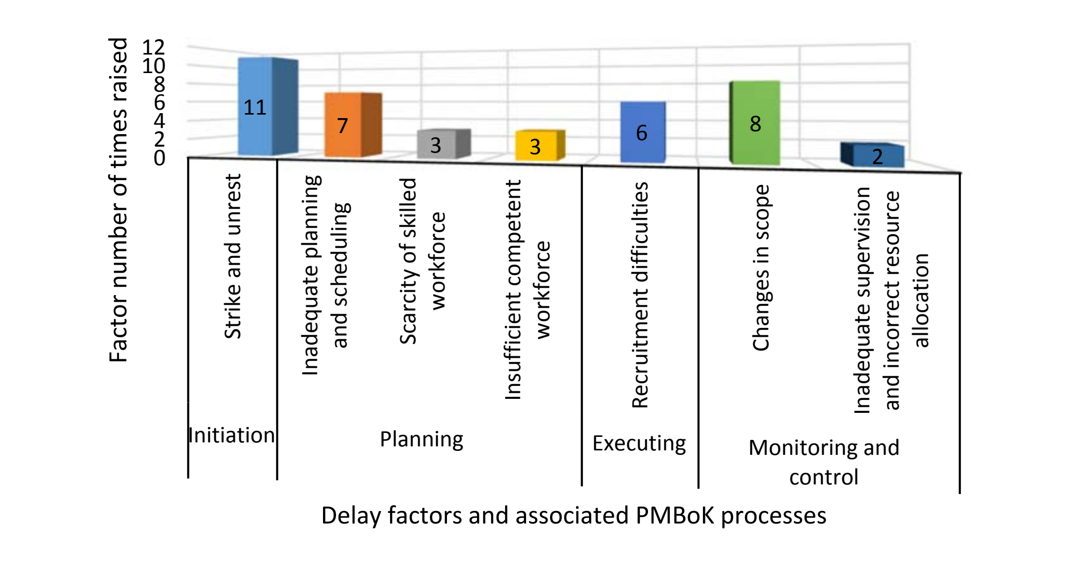


Figure 5. Main delay factors grouped in accordance with PMBoK Processes

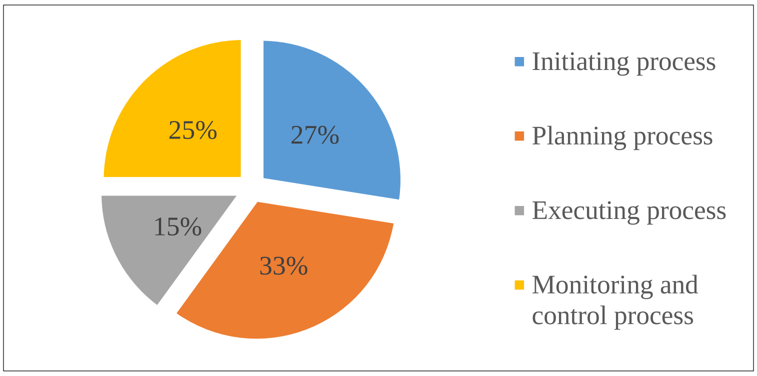


Figure 6. Delays distribution using PMBoK Processes

## 4.2. Effects of Delays

Following the analysis of collected data, the following effects of delays were identified: time-overrun is raised ten times, poor workmanship due to pressure is mentioned seven times, followed by increased project costs mentioned three times. Safety risks are mentioned twice. Stress on the workforce, an unhappy client, bad reputation for the contractor and idling resources were all mentioned once respectively. Poor project execution increases project risks for failure, late start of the project and late recruitment of the workforce are the four emerging effects that appear as unique to a boiler maintenance project.

Table 3. Effects of delays identified

| Effects of delays raised | Number of times mentioned |
|---|---|
| Time-overrun | Ten times |
| Poor workmanship due to pressure | Seven times |
| Increased project costs | Three times |
| Safety risks | Twice |
| Creates stress | Once |
| Poor project execution | Once |
| Increases risks for failure | Once |
| Unhappy client | Once |

| Effects of delays raised | Number of times mentioned |
|---|---|
| Contractor bad reputation | Once |
| The late start of the project | Once |
| Idling resources | Once |
| Late recruitment of workforce | Once |

## 5. Discussion of Results, Recommendations and Conclusion

### 5.1 Discussion of Results

The analysis from both the open-end questionnaires and project documents shows the following: strike and unrest mentioned, changes in scope, inadequate planning, recruitment difficulties, inadequate competent workforce, the scarcity of skilled workforce, inadequate supervision and resource allocation are main factors contributing to delays during half station shut down. Low productivity is the factor identified in the project documents but not identified from the responses received from the open-ended questionnaires.

The Pareto analysis indicated the top twenty percent factors contributing to delays, the top twenty factors were further reduced into the five PMBoK's standard processes adopted from by Zarei et al. (2018) as illustrated in Figure 5. From data presented in Figure 5, it is evident that most of the factors contributing to delays are planning related. Figure 6 demonstrates that forty-eight percent of factors contributing to delays are planning related.

The study identified the effects of delays as, *inter alia*, time-overrun, poor workmanship due to pressure, increased project costs, safety risks and idling resources. The findings from the qualitative analysis revealed that most respondents involved in the boiler maintenance believe time-overrun is the leading effect of delays, mentioned ten times, followed by poor workmanship raised seven times and increased project costs raised three times. The project document, project schedule confirms the extension of time in the boiler maintenance. Poor workmanship is identified with the high repair rate in the project document. These repairs have cost implications. Comparing the findings presented in Figure 4 and Table 3 against the literature and project documents, a fair similarity exists. Regarding the effects of delays, poor project execution, increase in project risks for failure, late start of the project and late recruitment of the workforce are the four emerging effects that appear as unique to boiler maintenance project in this study.

Although the study adopted a deductive approach, open-ended questions are inductive in nature. Due to the inductive nature of the questions, the emerging effects of delays are expected. These emerging effects highlight the uniqueness of every project and the profile of respondents. The emerging effects present opportunities for further assessment in future studies. Samarghandi et al. (2016) and Durdyev et al. (2017) confirmed that results of studies involve delays and their effects are influenced by the nature of the project and the profile and designation of the participants.

### 5.2 Recommendations

The data analysis indicates that there are sixteen factors contributing to delays in the boiler maintenance project. From a practical perspective, it is not feasible for a company to attend to all factors simultaneously. From the Pareto chart, seven primary factors contributing to delays are identified, comprising of strike and unrest, changes in scope, inadequate planning and scheduling, recruitment difficulties, insufficient competent workforce, scarcity of skilled workforce and inadequate supervision and resource allocation.

From the collected data and literature review, the following strategies for dealing with the main factors contributing to delays are derived:

- Labour and community strike and unrest: stakeholder engagement, workforce, and local community buy-in through empowerment.
- Changes in scope of work: a difficult factor to control due to several dynamics, however; collaboration during scope generation, clear definition of scope, improve control process, better prioritisation and adherence to maintenance strategies are suggestions from the collected data and the literature.
- Inadequate planning and scheduling: stakeholder involvement in the planning phase, improve planning and knowledge sharing is advised.

- Recruitment difficulties: regarding this factor, no strategy is identified in the literature. The respondents suggest the assessment of the pre-employment verification process.
- Inadequate competent workforce: prominence is given to investing in training for workers and conducting adequately planned employment pre-qualification process.
- The scarcity of skilled workforce: to deal with the scarcity of skilled workforce, personnel capacity building, retaining competent individuals and investing in training are suggested.
- Project complexity: to deal with project complexity, feasibility studies, adequate planning and thorough assessment of the project scope is mentioned.

### 5.3 Conclusions

There are several dynamics to factors contributing to delays, and these dynamics are not common for all projects. This study explored factors contributing to delays and their effects in the boiler maintenance during half station shut down in the coal-fired power plant. A deductive thinking and qualitative approach are used to answer the research questions. From the analysis sixteen main factors contributing to delays are identified:(1) strike and unrest, (2) changes in scope, (3) inadequate planning and scheduling, (4) recruitment difficulties, (5) insufficient competent workforce, (6) scarcity of skilled workforce, (7) inadequate supervision, (8) project complexity, (9) poor workmanship, (10) ineffective communication, (11) material and equipment delivery, (12) errors in design, (13) unrealistic project duration, (14) quality management and monitoring challenges, (15) inadequate coordination of resources, (16) emergency breakdowns.

Furthermore, twelve effects of delays were identified: (1) time-overrun, (2) poor workmanship due to pressure, (3) increased project costs, (4) safety risks, (5) creates stress, (6) poor project execution, (7) increases risks for failure, (8) unhappy client, (9) bad reputation for contractor, (10) the late start of the project, (11) idling resources, (12) late recruitment of workforce. Mitigations for dealing with top-twenty percent of factors contributing to delays based on the Pareto chart are also presented. It is worth noting that the mitigations suggested in this study are more proactive than reactive.

It is important to highlight that some factors contributing to delays and their effects are unique to the specific project, environment or countries, including, in this research, although not part of the main contributing factors, delay factors of time-keeping by the workforce and retraining of the workforce. Effects that are unique include poor project execution, increased risks for failure and late start of the project.

From the literature review, previous studies showed a significant amount of research on delays and their effects, however, most of the studies conducted are in the civil environment with little on factors contributing to delays in energy utility maintenance projects, specifically in the coal-fired power plant, boiler maintenance. As a significant contribution, this present paper adds to the body of knowledge regarding delays and their effects in the energy utility maintenance projects, specifically boiler maintenance. These findings could be of value to academics. Furthermore, the practitioners can use the findings to develop an understanding of the different dynamics that contribute to delays and make efforts to minimise the occurrences of delays.

This study focused on boiler maintenance in a specific plant, by exploring factors contributing to delays and their effects, therefore, the results presented in this paper cannot be generalised. Similarly, the study does not address the root causes of delay factors. As indicated above, the study was conducted in a single coal-fired power plant in the Southern African context, it would, therefore, be beneficial to conduct a comparison study across all the coal-fired power plant in South Africa for further validation of the findings presented in the paper. Furthermore, most previous studies focused on factors contributing to delays and the effects of delays. Studies that investigate and consider strategies for dealing with delays are minimal. Researchers are encouraged to consider adding to the solutions and mitigation of factors contributing to delays in their environment of expertise.

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