ENGINEERING CONSTRUCTION AND ARCHITECTURAL MANAGEMENT

DOI: 10.1108/ECAM-07-2022-0658

Accepted: 31 October 2022

Examining Critical Project Management Skills for Successful Delivery of Major Maintenance Projects: Insights from the United Kingdom Energy Sector

[1]Bryan Pieterse, [2]Kofi Agyekum, [1] Patrick Manu, [1]Saeed Reza Mohandes, [1]Clara Cheung, and [1]Akilu Yunusa-Kaltungo

[1] Department of Mechanical, Aerospace and Civil Engineering, The University of Manchester, UK

[2] Department of Construction Technology and Management, Kwame Nkrumah University of Science and Technology, Kumasi Ghana

Corresponding Author: Patrick Manu, Patrick.Manu@manchester.ac.uk

Abstract

Purpose - Major maintenance projects are often regarded as maintenance activities regardless of their complexity and scale. Consequently, very scarce research attention has hitherto been paid to the critical skills required when undertaking these projects. More specifically, the body of relevant knowledge is deprived of a study focusing on maintenance projects within the energy sector. In view of this shortcoming, this research examined the critical project management skills required to deliver major maintenance projects within the energy sector.

Design/methodology/approach – Based on a quantitative research strategy, this study addressed the knowledge gap through a cross-sectional survey of professionals involved in the delivery of major maintenance projects in the United Kingdom's (UK) energy sector. Data obtained was analyzed via descriptive (e.g., frequencies, mean and standard deviation) and inferential statistical analyses (One-sample t-test and Exploratory Factor Analysis (EFA)).

Findings – Out of the 45 project management skills identified in the literature and examined by the respondents, the results obtained from the One-sample t-test (based on p (1-tailed) $\leq$ 0.05) showed that thirty-seven were considered to be at least "important", accounting for 80.4% of all the skills identified. Exploratory Factor Analysis (EFA) revealed a clustering of the project management skills items into seven components: "skills related to work scheduling and coordination"; "communication, risk, safety and stakeholder management skills"; "quality assurance skills"; "people management skills"; "skills related to forecasting scope and duration of outage"; "implementation of processes and time management skills"; and "technical/engineering skills and experience pertaining to the outage and local site knowledge".

Originality/value – This study has identified and contributed to the limited state-of-the-art skills project managers must possess to manage major maintenance projects in the energy sector successfully. The findings would be useful to organizations within the energy sector in ensuring that they have suitable personnel in place to deliver major maintenance projects on their assets.

Keywords: Asset maintenance, Maintenance strategies, Project management skills, Energy Sector, Survey.

1. Introduction

Projects in business environments are considered not only solutions to technical problems but also a way to improve business and implement changes (Berssaneti and Carvalho, 2015). The United Kingdom (UK) government defines vital infrastructure as those critical elements of infrastructure (facilities, systems, sites, property, information, people, networks, and processes), the loss or compromise of which would result in a major detrimental impact on the availability, delivery or integrity of essential services, leading to severe economic or social consequences or loss of life (Cabinet Office, 2019). The Energy Sector is one of the thirteen Critical National Infrastructure sectors in the UK, which has five sub-sectors: Upstream Oil & Gas, Downstream Oil, Downstream Gas, Electricity, and Smart Energy (National Cyber Security Centre, 2020).

Large-scale maintenance projects in the energy sector are undertaken on physical assets periodically to ensure their continued safe and efficient operation. Maintenance projects within this sector are renowned for being complicated projects with high levels of risk associated with them due to extremely high levels of uncertainty associated with periodic inspections of critical components (Hlophe and Visser, 2018; Mtembi and Kanakana, 2015; Levitt, 2004). Typically, large-scale maintenance projects associated with the assets in the energy sector are known colloquially as outages, shutdowns, or turnaround maintenance (Hlophe and Visser, 2018). However, to avoid confusion, the term "major maintenance project" is used throughout this article. A maintenance project is one that keeps a facility or asset in efficient operating condition, preserves the condition of the property, or restores the property to a sound state after prolonged use. A major maintenance project is period of maintenance in which plants are shutdown to allow for inspections, replacements, and overhauls that can be carried out only when the assets are out of service (Ben-Daya et al., 2016).

Despite their complexity and scale, major maintenance projects are often regarded as maintenance activities. Consequently, there is limited project management literature specifically associated with these events and limited literature regarding the skills required when managing these types of events. Plentiful literature exists regarding the skills required of a project manager (see Association for Project Management, 2015); however, there is a dearth of research specific to major maintenance projects in the energy sector. Among the limited related research are the studies by Hlophe and Visser (2018), Obiajunwa (2013), and Pokharel and Jiao (2008). Hlophe and Visser (2018) focused on risk management during outage projects at power plants in South Africa. Though relevant, risk management is only one of several domains of project management competencies (see Association for Project Management, 2015). Therefore, the study does not cover a sufficient breadth of project management skills required to deliver major maintenance projects in the energy sector.

Furthermore, the study by Obiajunwa (2013) focused on generic management skills required to manage turnaround maintenance in process plants, while Pokharel and Jiao (2008) provided a case study of turnaround maintenance management in a lubricating oil-producing plant. Though Pokharel and Jiao (2008) did not specifically focus on project management, they reported the utility of project management practice in addressing issues and optimizing cost and schedule. Taken together, the extant studies related to the subject of inquiry do not provide sufficient insights regarding the critical project management skills needed to deliver major maintenance projects in the energy sector successfully. Drawing on the foregoing discussion, there is, therefore, the need to interrogate the critical project management skills required to deliver major maintenance projects within the energy sector successfully. The research question that arises from this problem is *what critical project management skills are required for the successful delivery of major maintenance projects in the energy sector in the UK*? To answer this question, this study aims to examine the critical project management skills required to deliver major maintenance projects within the energy sector. The specific objective includes identifying and analyzing the critical project management skills required to deliver major maintenance projects within the energy sector.

This article commences with the introduction to the study, discussing the problem, and the specified goal. It then carries out a comparative review of the related literature on the socio-economic significance of the UK energy sector, its maintenance issues, and skills associated with major maintenance projects. Subsequently, the research methodology, findings, discussions, and conclusion are presented.

This study's theoretical and practical contributions are enormous. Theoretically, this study bridges an important gap in the body of knowledge and further contributes to the state-of-the-art on the critical project management skills required to effectively deliver on major maintenance projects in the energy sector. The skills identified are peculiar to the energy sector, something which is limited in the literature. Practically, the results of this study could inform the energy sector businesses, stakeholders, and policymakers about which project management skills to critically develop to ensure that the sector achieves its desired outcome.

2. Literature review

This section reviews literature pertinent to the theme under investigation. The literature was reviewed to meet the specific objective of this study. The review covers the following areas: Project maintenance management; Maintenance activities in the lifecycle of an energy project; The energy sector and its socio-economic significance: Global and the UK; Asset Maintenance and Skills a project manager must possess for major maintenance projects in the energy sector.

2.1 Project maintenance management

Maintenance is defined by the British Standard Glossary as "the combination of all the technical and administrative actions, including supervision actions, intended to retain an item in or restore it to a state in which it can perform a required function" (BS EN 13306, 2010). It is a set of organized activities that are carried out to keep an item in its best operational condition with the minimum cost required (Patino-Rodriguez and Carazas, 2019). Effective maintenance work involves a series of tasks. According to BS-EN-60300 (2009), maintenance tasks are a sequence of elementary maintenance activities which are undertaken for a given purpose. A maintenance project is one that keeps a facility or asset in efficient operating condition, preserves the condition of the property, or restores the property to a sound state after prolonged use. A major maintenance project is period of maintenance in which plants are shutdown to allow for inspections, replacements, and overhauls that can be carried out only when the assets are out of service (Ben-Daya et al., 2016). Maintenance management includes all the activities of the management that determine the maintenance objectives, priorities, strategies, and responsibilities, and implement them utilizing planning, control, and supervision (BS EN 13306, 2010).

Proper maintenance management will ensure that physical assets perform their required functions efficiently and effectively. The concept of maintenance consists of different functions. For instance, within the manufacturing environment, the functions include maintenance of existing machinery, diagnosis of existing plant equipment, equipment inspection, maintenance of existing plant utilities, completion of repairs within a timely fashion, and protection of the operator by safeguarding the plant (Moynihan et al., 2002).

Within the construction environment, maintenance includes all the services that are required to assure that the building will perform the functions for which it was designed and constructed (Laila, 2015). Within the energy sector, power plants, generators, sub-stations, and other equipment have become technologically sophisticated. Hence, there is the potential for any interruptions in the power supply to cause losses to the industry and the economy. Therefore, Alamri et al. (2022) posit that the importance of maintenance with enhancing availability, performance efficiency, on-time deliveries, safety necessities, and overall plant productivity becomes more necessary.

2.2 Maintenance activities in the lifecycle of an energy project

Every energy project, irrespective of the resources involved has a lifecycle consisting of four stages, i.e., Development (comprising initiation and planning), Construction and installation, operations and maintenance, and closure (Alberta Energy Regulator, 2022). The development phase initiates and plans the project. Project initiation defines and authorizes a project (PMBoK, 2017). Any company that decides to initiate an energy project must plan the project, carry out stakeholder engagement with the indigenous community, and obtain approval from the necessary authorities. The company must carry out the needed assessment of the area where the project will be undertaken, notify any persons that could be impacted by the project, and apply and receive the needed approval from the authorities before work commences. During the planning of the energy project, it is important to plan the maintenance task. Planning the maintenance activities include deciding on what exactly needs to be done, determining the priority, and defining the sequence of activities and skills that will be required during the operation and maintenance phase of the project.

At the construction and installation phase, approval is given for work to commence. Financial resources are required for the maintenance of the project during this phase. The allocated budget size will depend on the complexity of installation as well as the obligation to ensure continuity in operation (Andruşcă, 2012).

In an industry, operation and management refer to a set of procedures that following the installation and commissioning of a system aims to keep it operational for a desired length of time under economic constraints. Adapting this description, the operation, and maintenance phase of an energy project could be described as that phase where the project is operated and maintained for a desired length of time under economic constraints. Operations and maintenance are recognized as major contributors to the overall cost of energy projects, typically amounting to 25-30% of the lifecycle costs (Rinaldi et al., 2021). The costs involved in operations and maintenance can either be fixed or variable (Rinaldi et al., 2021). The fixed costs could include regular device checks and tests, insurance costs, use of facilities, etc. (Rinaldi et al., 2021). The variable costs change based on the number of operations, as well as unpredicted or unscheduled interventions (Rinaldi et al., 2021).

2.3 The energy sector and its socio-economic significance: Global and the UK

There is an increasing demand for energy among contemporary societies and the global economy (Cirella and Pawlowska, 2021). Energy is the driving force behind development and it plays a crucial role in running the modern global system (Cirella and Pawlowska, 2021). The significant relation between energy and economic progress is well recognized by policymakers globally. The coupling between socio-economic development patterns and energy demand has been identified as a fundamental issue for understanding the scale and structure of energy demand (Csereklyei and Stern, 2015). Energy represents a key component of industrial development, which is needed to help other sectors function.

While governments and businesses are increasingly committed to decarbonization targets, energy markets face extreme volatility driven by geopolitical tensions and a rebound in energy demand (Global Energy Perspectives, 2022). The global energy demands and emissions increased by 5% compared to 2020 (Global Energy Perspectives, 2022). By 2050, the electricity demand is projected to triple, and renewable generation is projected to reach 80-90%. Also, peak oil demand is projected to occur between 2024 and 2027 (Global Energy Perspectives, 2022). The demand for gas could also increase by 10-20% towards 2035. These projections depict that the total investments across all energy sectors could grow by more than 4% per annum (Global Energy Perspectives, 2022).

Energy is an essential service within the UK economy; homes and businesses use energy to provide light, warmth, and other essential services such as sewage treatment, clean drinking water, and medical care. According to Armaroli and Balzani (2011), energy is embedded in any type of good and is needed to produce any kind of service. Ofgem (2019), indicated that energy is one of the most significant single items of regular expenditure for households and businesses in the UK, who together spend over £50 billion on energy each year.

According to Energy UK (2020), the energy industry underpins the entire UK economy and supports more than 738,000 jobs. The energy industry also invested £13bn in the UK in 2019 and generated £95 billion in economic activity through the supply chain (Energy UK, 2020). Energy UK (2020) states that the UK has one of the cleanest and most innovative energy systems in the world; however, further investment into this sector is still required not only to continue the progression towards a low-carbon economy but also to improve the UK’s energy security.

Consumption of energy within the UK is variable throughout the year. The peaks and troughs are predominantly related to domestic users, and more energy is consumed during colder seasons. The final energy consumption in the peak quarters is around 40 to 45 million tonnes of oil equivalent across all end users. The total final energy consumption (excluding non-energy use) in 2020 was at a record low level (13 percent lower than in 2019) due to “consumption levels [being] severely impacted by the Covid-19 pandemic lockdown restrictions” (Department for Business, Energy & Industry Strategy, 2021, p. 3).

Whilst the energy market is all-encompassing, the electricity (or power) sector is often used as an indicator for progress towards the ambitious net-zero target. The power sector has changed significantly over the past few years. It continues to change as the nation transition[s] from a large-scale conventional fossil fuel-dominated generation mix to intermittent renewable generation. Over the past few years, the power sector has seen a marked increase in output from wind and solar farms (Ofgem, 2021). In 2019 renewables were responsible for “37% of all generations compared to 33% in 2018 and only 7% ten years ago” (Energy UK, 2020, p.

12). In addition to the change in generation by fuel type, the “power sector has reduced its emissions by 72%” since 1990, and “in 2019, it decreased its emissions the most compared to other sectors for the sixth consecutive year, by 13%” (Energy UK, 2020, p. 12).

In June 2019, parliament passed legislation requiring the government to reduce the UK’s net emissions of greenhouse gases by 100% relative to 1990 levels by 2050, a target of “Net Zero” (as opposed to *gross zero*). HM Treasury (2020, p. 2) believes that “achieving Net-Zero will result in new technologies, industries, and jobs as existing sectors begin to decarbonize their existing processes and change their products and services to offer low prices carbon equivalents”. HM Treasury (2020, p. 4) noted that "the amount of investment required to reach net-zero and the consequential impacts on operating costs are difficult to estimate”. According to Institute for Government (2020), the Committee on Climate Change (2019) puts the cost associated with reaching Net Zero at £50bn per year, whilst the Treasury and the Department for Business, Energy and Industrial Strategy (BEIS) put the figure nearer to £70bn per year, which is over £1 trillion by 2050. To achieve the net-zero target by 2050, the National Grid ESO (2020, p. 25) predicts that “utilizing offshore and onshore wind energy will continue to expand and ultimately dominate the UK Energy sector”. In addition, reliance on Fossil Fuels for Energy will be nil, and electricity will be exported to the continent rather than imported, as is typically the case in 2021. National Grid ESO (2020, p. 85) notes that “to achieve net-zero by 2050, most electricity will come from four technology types: wind, solar, nuclear, and Bioenergy with carbon capture and storage (BECCS)”. The National Grid ESO (2020, p. 6) also specifically stated that “Hydrogen and carbon capture and storage must be deployed for net-zero” and that to achieve net-zero by 2050, industrial-scale demonstration projects will need to be operational before the end of this decade (i.e. 2020 to 2030).

Numerous projects are underway to achieve the ambitious target of Net Zero 2050. Still, one that stands out is the Hinkley Point C project which has gained press attention for numerous reasons, but it is noteworthy that Hinkley Point C is the “first new nuclear power station to be built in the UK in over 20 years” (EDF Energy, 2021). This project has also garnered media attention for the numerous costs and delays associated with not only construction but generation subsidies too. In March 2013, the total investment in Hinkley Point C was predicted to be £16bn, which received particular attention due to the state aid that the UK Government provided in the form of a subsidy of £92.50 for every megawatt-hour (MWh) produced for 35 years (Power Technology, 2021). The project continues to receive attention due to spiraling costs and delays to planned completion, with an original commercial operation date for Unit 1 being 2023 (Power Technology, 2021) versus the current 2026 prediction and an increased cost of £23bn (World Nuclear News, 2021). EDF Energy (2021) estimated that the construction and operation of Hinkley Point C would create 25,000 employment opportunities and up to 1,000 apprenticeships, and 64% of the project’s construction value is predicted to go to UK companies.

2.4 Asset maintenance

Given the significant investments in physical assets demonstrated in Sections 1 and 2.3, it would seem logical that the developers would be anticipating a return on their investment. The return on investment is achieved by delivering a product/service (such as electricity or frequency response services) to the customer (The National Grid) using converting materials (Gas, Coal, Wind, etc.) into the aforementioned product/service. The above description is a simplified process of how the assets create a benefit to the developers and does not consider the competitive environment in which the assets will operate. The new assets will be competing against other new and existing assets with a range of technologies in an industry subject to complex national constraints, including continuously fluctuating raw materials or wholesale prices and being subjected to numerous strict regulatory frameworks. To ensure that the developers continue to receive the benefits of operating in this environment and that competitive advantage is maintained, the assets will need to be maintained, and upgrades will sometimes be required. Duarte and Scarpin (2022) noted that there is a relationship between maintenance and production, by which maintenance is a support activity that ensures that the production function can achieve the targets of production.

Lenahan (2005) and Levitt (2004) also acknowledged that maintenance and production have a shared relationship; however, they both continue to explore significant maintenance projects further and recognize that these events conflict with just about everything else going on at any time (Levitt, 2004). Maintenance is required to ensure the plant remains reliable, profitable, and safe. However, major maintenance projects have an inherent risk of diminishing reliability or efficiency if not planned and executed correctly; they typically have high costs associated with them, not only in terms of labour and materials but also in terms of lost production. Industry reports show that 35% to 52% of maintenance budgets are expended on major maintenance projects, which excludes the costs of lost production (Kister & Hawkins, 2006). Furthermore, due to the increased on-site activities, there is an increased risk of harm to people, property, and the environment (Lenahan, 2005). Production is lost as specific actions can only be carried out whilst the plant is offline; activities may include but are not limited to statutory inspections, inspections of critical equipment, overhauls, modifications to the plant, etc (Iheukwumere-Esotu, and Yunusa-Kaltungo, 2021). In some instances, the value associated with the loss of production is more significant than all the costs related to the major maintenance project itself (Iheukwumere-Esotu and Yunusa-Kaltungo, 2020a). Given the potential losses associated with major maintenance projects, there will always be an argument for avoiding them. There is also an argument for ensuring that they are as short as possible but long enough to ensure that the scope can be accommodated. The timing and scope of a major maintenance project also need careful consideration and balance of the requirements of the business (including business performance), the operating market, competitive advantage (including potential modifications), legal requirements, health and safety, and impacts on the local community (Iheukwumere-Esotu and Yunusa-Kaltungo, 2020b).

2.5 Skills a project manager must possess for major maintenance works in the energy sector

The role of the project professional and the skills that are needed must be examined within the context of the organizational framework for the project management process (Robert and Goodwin, 1992). The energy sector significantly and strategically impacts the socio-economic development and growth of every country (González et al., 2016). The EIA (2013) estimated that between the period 2013-2040, global energy consumption is estimated to increase by approximately 56%. Further increase in this trend implies that the global energy sector will be confronted with the challenge of undertaking major construction and engineering projects to assemble new energy installations (González et al., 2016). This means that how projects are developed and managed will attract global attention. Therefore, in the next few decades, there is the potential for project manager attributes and characteristics to draw more attention from researchers, organizations, and the like (González et al., 2016).

In the view of Olsen (2018), major maintenance projects extend far beyond the traditional view of just being maintenance-even. Major maintenance projects require project management discipline to deliver the work scope efficiently and successfully. According to Robert and Goodwin (1992), any successful approach to managing a plant shutdown must be based on principles of sound project management. Obiajunwa (2013) compliments Robert and Goodwin's assertion through his research, noting that there are specific management skills particular towards ensuring the successful management of projects. In addition to the above, Lenahan (2005) observed that the management of major maintenance projects is project management of a special kind, and Pokharel and Jiao (2008) suggested that it is essential to apply project management techniques during the delivery of operational projects and maintenance of complex processes.

Skill requirements in the labour market have been an emerging research arena (Lyu and Liu, 2021). Literature has extensively reported on skill requirements across various industries. Unfortunately, detailed analysis of skill requirements across different occupations in specific sectors like energy remains underexplored (Lyu and Liu, 2021). For instance, in the energy sector, the introduction of computerization and digitalization has introduced additional skills that remain unexplored (Lyu and Liu, 2021). According to PMI (2017), the project manager is accountable for the success of a project. Effective project management is argued to play a critical role in driving project success, typically defined through the achievement of the iron triangle of time, cost, and quality objectives of the project (Ngo and Hwang, 2022). This means that the required skills and attributes of a project manager must be understood by those who aspire to become a project manager and those responsible for selecting project managers. The Association for Project Management, APM, (2013) indicated that when a project manager deploys interpersonal skills, he provides an opportunity to create high-performance teams, builds individual effectiveness and confidence, and fosters success.

Recognized project management associations and institutions in the field of modern project management identify key project management skills and competences required for managing all kinds of projects. The Project Management Institute (PMI) has developed the Project Management Body of Knowledge (PMBOK), The Project Manager Competency Development (PMCD) Framework, and the Code of Ethics and Professional Standard that applies to project Managers. The key PM skills outlined by the PMI are listed to include communication, leadership, management, cognitive skills, effectiveness, and professionalism (González et al., 2016). The International Project Management Association (IPMA) has developed the IPMA Competence Baseline (ICB) which relates to three key elements of competence, i.e., technical, behavioural, and contextual (González et al., 2016). The Association of Project Management (APM) has developed the APM Body of Knowledge which relates to the interpersonal skills required of project managers. In addition to this, the Body has also developed the APM Competence Framework which outlines thirty technical, nine behavioural, and eight contextual competence elements required of an effective project manager (APM, 2013). The International Standard Organization (ISO) also provides some guidance on project management related to the competencies of project personnel (ISO 21500:2012). Finally, the Australian Institute of Project Management (AIPM) Professional Competency Standards for Project Management Part C outlines the underpinning knowledge and skills required of an effective project manager.

These developments from these professional bodies only outline skill sets required for general project management practice. Notwithstanding these proposals, not much is reported on specific project management skill sets required to undertake major maintenance projects. A review of the related literature to identify project management skills and, where possible, project management skills that have been discussed in conjunction with maintenance projects is summarised in Table 1.

[Insert Table 1]

Table 1 is a matrix presentation of the forty-five (45) skill sets obtained after the literature search. Out of the forty-five skill sets, twenty-three were obtained from APM (2015), fifteen were obtained from Obiajunwa (2013), eleven (11) were obtained from Al-Turki et al. (2019), fifteen (15) were obtained from Duffuaa and Daya (2004), eighteen were obtained from Ben-Daya et al. (2016), thirteen were obtained from Pokharel and Jiao (2008), Smith (2001) contributed seventeen (17), Odusami (2002) contributed twenty-four, PMI (2017) contributed eighteen (18), Robert and Goodwin (1992) contributed ten (10), and Ngo and Hwang (2022) contributed eight (8). It is not surprising that budget management is one of the commonly discussed skills in the literature (Table 1), given that any project has a relationship with money. Skills associated with planning, scheduling of works, and resource management are also common in the literature. These occurrences are relatable to The Iron Triangle, which refers to the three elements (i.e., cost, time, and quality) by which a project's success is often measured (Albert et al., 2017). According to Albert et al. (2017), The Iron Triangle has been widely discussed in the literature and is often used to inform different approaches to various measures of project success (Serrador, 2015; Chang et al., 2013; McLeod, 2012). It is worth noting that many arguments exist which suggest that a successful project can only conform to two of three sides of The Iron Triangle. Notwithstanding, completing a major maintenance project safely, on time, and cost is not enough in itself to be considered a success, but that to be considered a success the major maintenance project scope needs to be geared towards the over-arching objective of achieving optimum plant performance.

3. Methodology

Aligned with the study's aim, the study sought to gain a generic view of the critical project management (PM) skills required to successfully manage a major maintenance project within the UK energy sector. The study adopted a positivist deductive research paradigm using a quantitative (survey strategy) research strategy for investigating the critical PM skills required to successfully manage a major maintenance project within the UK energy sector. According to Fellows and Liu (2015) and Creswell and Creswell (2018), the quantitative research approach is recommended where one seeks to obtain a generalized view of a phenomenon. Consequently, a survey strategy was adopted. The use of a quantitative strategy for this study implied that the key phenomenon under investigation was being viewed as a single reality that, can be observed and assessed objectively. In this study, the use of a cross-sectional survey thus enabled the capture of the experiences and perceptions of a wide range of personnel involved in the energy sector in the UK. An overview of the research process is is shown by Figure 1. Subsections 3.1-3.4 expounds on the elements of the figure.

[Insert Figure 1 here]

3.1 Review of related literature

This study carried out a mini-scoping review. Grant and Booth (2009) defined a scoping review to encompass a preliminary assessment of the potential size and scope of available research literature. Scoping reviews are recommended when a body of literature has not yet been comprehensively reviewed or exhibits a large, complex, or heterogeneous nature not amenable to a more precise systematic review. This type of review was considered necessary for this study because, given the similarities between the traditional view of traditional project management and the management of major maintenance projects, it is appropriate to use the skills associated with a project manager to define the suggestive list of skills that an active professional within a major energy sector maintenance project may require. There still exists an argument that the motivations and success factors of the two may differ, and as such, it is vital to delve deeper into the importance of each skill attributed to the professionals who undertake major maintenance projects in the energy sector.

Peters et al. (2021) suggested that a scoping review may consist of all or some of these stages, i.e., timeframe, question, sources and searchers, selection, appraisal (optional), synthesis, and consultation (optional). It is important to note that the current study is original research and not a review paper; hence, much emphasis was not laid on these stages as suggested by Peters et al. (2021). The literature searches on the theme under investigation (i.e., critical skills of project managers involved in major maintenance works) spanned over 21 years (i.e., from 2001-2022). This period was considered because it supplied the researchers with the needed information necessary for this study (see Table 1). The major question that was posed to assist in arriving at these literature sources was "*what critical project management skills are required for the successful delivery of major maintenance projects in the energy sector*"? Because of the narrowness of the question, i.e., PM skills for maintenance projects, the search was opened across broader search tools like Scopus, Emerald Insight, Google scholar, and the like. The search revealed a limited number of academic research papers, reports, books, etc. on the theme. The most important ones were settled on to be used for this study. In addition to Table 1, which summarizes the key skills used in this study, other relevant literature sources obtained from the search cut across all the other sections of the literature review (please see sub-sections 2.1-2.5).

3.2 Survey design

A questionnaire was designed for the survey. It consisted of two main parts: background information (demographic profile) and relevance of project management skills/competencies.

Part 1 – demographic profile. This section sought to collect the professional background information of respondents to determine the demographic background of the respondents, specifically about the roles they have undertaken within a major maintenance project and the frequency to which they have been exposed to these events.

Part 2 - relevance of project management skills/competencies. This section required the respondents to score on a Likert scale of 1 to 5 (where 1 = Not important, 2 = Slightly important, 3 = Moderately important, 4 = Important, 5 = Very important) the relevant project management skills that are required when undertaking major maintenance projects. The skills incorporated into this section covered technical and soft skills. The skills used within the questionnaire were 45 in number and were collated from multiple literature sources, as shown in Table 1.

3.3 Survey administration

Before the final sets of questionnaires were sent out, they went through multiple rounds of review and revision by senior persons with both research and industry expertise in project management to ensure their suitability. The target population for this study was professionals involved in the delivery of maintenance projects in the UK energy sector. This was used as the main criterion for identifying suitable respondents. Based on this criterion, the purposive and snowball sampling approaches (non-probability sampling approaches) were used to locate the respondents for the study. The purposive sampling helped the researchers locate potential participants who are working with energy companies. Given the difficulty in obtaining participation in a survey, the research team drew on their experience within the energy industry and also utilized their relevant industry contacts. Although the use of these approaches is justifiable because of the lack of a sampling frame, purposive sampling could be prone to researcher bias compared to the probability sampling techniques (Agyekum et al., 2022).
An online questionnaire was designed using an online tool called “Qualtrics”, and a link to the questionnaire was emailed to the contacts requesting their participation in the research. The “snowball technique” was further used as a compliment and, within the body of the email, requested that the participants forward the email containing the link to the survey to contacts

within their network who may be participants in this research. Follow-up reminder emails were sent regularly to remind participants that their input had been requested in a drive to improve the number of responses obtained. A total of sixty-seven (67) responses were received, of which five were excluded due to excessive missing data. In total, sixty-two (62) responses were used for the data analyses. This sample size was considered adequate because the central limit theory holds with a sample size greater than 30.

3.4 Data Analyses

The questionnaire data were coded into IBM SPSS Statistic 24 for analysis. SPSS was used to undertake descriptive statistical analyses (e.g., frequencies, mean and standard deviation [SD]) and inferential statistical analyses – One sample t-tests and exploratory factor analysis (EFA). The reliability analysis of the data collected was carried out to assess its integrity and to determine if any of the factors did not significantly contribute to the overall reliability of the data obtained. If for any reason any of the factors was found to be unreliable, it must be excluded from the EFA. The Cronbach Alpha test was performed to determine the reliability of the instrument. This test is especially important when using a Likert scale type of question, similar to the one adopted in this study. According to Field (2013), this analysis helps determine the internal consistency of the instrument and the credibility of the data collected. The value of the Cronbach Alpha coefficient ranges from 0 to 1. Field (2013) indicates that a value above 0.7 shows a satisfactory level of consistency within the data and a value above 0.8 represents a high level of internal consistency. The reliability analysis performed returned Cronbach Alpha values of 0.918, 0.864, 0.868, 0.831, 0.879, 0.829, and 0.759 for the seven components (see Table 4). These values represent high levels of internal consistency.

T-test allows the statistical examination of sample means (Field, 2013) and has been applied in previous construction management studies (Mahamadu et al., 2018). In this study, One sample t-test was carried out to determine whether the sample population considered a specific skill important. The null hypothesis for assessing critical project management skills was that the skill is not important (H0: U = U0), and the alternative hypothesis was that the skill was important (Ha: U > U0), where U0 is the population mean (U0 was fixed at 3.5, drawing from Mahamadu et al. (2018). Thus, based on the five-point Likert rating scale, a skill was deemed to be important if its respective mean score was significantly greater than 3.5 (which approximates to 4, i.e., “agree” that a skill is important).

The large number of critical skills identified in this study demanded the use of EFA to supplement the analysis conducted. The EFA was used to determine the underlying dimensions of the critical PM skills required to successfully manage a major maintenance project within the UK energy sector. Although a sample size of 62 was used in this study, the EFA was still considered adequate. According to Field (2013), there is still not a clear consensus amongst statisticians about the right sample size needed for factor analysis. Therefore, this has led to the use of several rules of thumb including the 5:1 ratio. For instance, in the views of Osborne and Costello (2004), a sample size of at least 100 or five times the number of variables to be included in the principal component analysis is required. On the other hand, Kyriazos (2018) recommended that irrespective of the conventional rules, the correlation between sample size and several variables is not a significant reason for ascertaining stability but rather component saturation and absolute sample size. Field (2013) also postulated that the absolute sample size is not the only variable to consider in ascertaining the suitability of factor solution but the absolute size of the factor loadings. de Winter et al. (2009) also indicated that EFA can yield reliable results for a sample size below 50, even in the presence of small distortions. Notwithstanding the several arguments on the suitability of a sample size, the EFA conducted with the data obtained in this study reveals the sample size of 62 was favourable. The appropriateness of the data was examined using Bartlett's test of sphericity and the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was used (Pallant, 2016).

4. Results and Discussion

The results are presented and discussed under two main sections: the demographic profile of respondents; and the relevance of the project management skills for major maintenance projects.

4.1 Demographic profile of respondents

The demographic information of the respondents (shown in Table 2) included their professional roles, positions within the organization, involvement in major maintenance projects, educational qualifications, and affiliation with a professional institute.

[Insert Table 2]

The above results indicate that the most appropriate respondents were identified, and as such, the data obtained (concerning the required skills for a major maintenance project) can be a credible and up-to-date reflection of their experiences encountered whilst undertaking a planned major maintenance project. This demographic information implies that most of the respondents were educated practitioners who are regularly involved in major maintenance projects. In addition, most of the respondents belonged to or were aspiring towards affiliation with a recognized professional institute (predominantly the Institution of Mechanical Engineers or the Institution of Engineering and Technology).

4.2 Important project management skills for major maintenance projects in the energy sector

The main body of the questionnaire was concerned with the level of importance of forty-six different competencies/skills to the respondents' most recent role undertaken within a major maintenance project. It was assessed using a five-point Likert scale (5= Very Important, 4 = Important, 3 = Moderately Important, 2=Slightly Important, 1 = Not Important).

4.2.1 One sample t-test analysis

To determine if the respondents felt that a particular skill or competency was at least "important", a One sample t-test was carried out using a value of 3.5, which would show that skills and competencies that score greater than 3.5 can be considered important. The results obtained from the one sample t-test (based on p (1-tailed) ≤ 0.05) show that thirty-seven skills are considered to be at least "important", which accounts for 80.4% of all the skills identified. All the skills identified have been re-ordered with their importance, based on the mean frequency of results. The complete details of the one-sample t-test results are shown in Table 3.

Based on their mean scores, the top twelve skills (i.e., those in the top third of important skills) are (in order of their importance): Communication Skills (Written & Oral); Safety Management; Decision Making; Leadership; Identification of requirements for, and ensuring compliance with relevant regulations and procedures; Ability to manage and analyze risks, opportunities and other issues; Stakeholder Management; Setting standards and managing them; Technical Experience (including experience of major maintenance projects); Time management; Organisational skills; and Quality Management.

[Insert Table 3]

Numerous authors (Khasanah et al., 2019; Association for Project Management, 2015; Ertl, 2015; Lenahan, 2005; Levitt, 2004) point to time, cost, quality, health and safety as being critical measures for project success. In addition to health and safety, the respondents to the survey also indicate time management skills and quality management as being important. Not only are they essential, but they also feature in the top third of the important skills. Nevertheless, skills associated with cost did not fare so well. Whilst the literature makes it apparent that skills related to budget management are important, this is in stark contradiction to the outcome of this study. When analyzed, the results show that the respondents consider that budget management is "not important" along with cost forecasting skills. According to van der Westhyssen (2014), major maintenance projects typically represent a significantly large proportion of an annual maintenance budget and, if mismanaged, have the potential to affect the company's bottom line and reputation. It is worth noting that Iheukwumere-Esotu and Kaltungo (2020c) state that 80% of major maintenance project-related activities sometimes exceed their costs by approximately 10%–40%. With so much at stake, it is little surprise that authors, scholars, and researchers are drawn to focus on this topic. However, why do these findings contradict the literature? Some light can be shed by the report written by Obiajunwa (2010), which indicated that budget management within the setting of a major maintenance project is particularly troublesome because the exact work scope is never indeed known or understood until such a point that all the work has been completed. To combat this uncertainty, the costs associated with the maintenance are all hedged around the uncertain, changing work scope and typically include an inbuilt contingency. In addition to this, there is an amount of anticipated remedial work, usually hedged around previous inspections and plant performance; however, the actual costs cannot be fully appreciated until all components have been thoroughly inspected. According to Obiajunwa (2010), the key to ensuring major maintenance projects remain within the allocated budget is scope management and resource management (i.e., balancing emergent work against non-critical work and keeping the resources productive). The respondents identified both skills (scope and resource management) as essential and ranked in the 16th and 22nd positions, respectively.

4.2.2 Exploratory factor analysis (EFA)

EFA was adopted to uncover the interrelationships among the variables (i.e., the PM skills items) to find out which variables could measure aspects of the same phenomenon that contributed to the project management skills for major maintenance projects in the energy sector. The results of the EFA are shown in Table 4. Bartlett's test of sphericity result obtained for the data is 2017.525 with an associated significance level of 0.000. These values suggest that the correlation matrix is not an identity matrix (Pallant, 2016). The KMO value of 0.75, greater than the acceptable threshold of 0.50, indicates that the sample is acceptable for factor analysis (Pallant, 2016). These two results indicate that factor analysis can further be used to group the factors.

Two stages (i.e., factor extraction using principal component analysis; and factor rotation using varimax rotation) was adopted for the factor analysis. The eigenvalue was set at 1.0, while the factor loading was set at 0.5, resulting in the extraction of seven components. The variances explained by each of the components is as follows: Component 1 = 37.901%; Component 2 = 11.789%; Component 3 = 7.504%; Component 4 = 4.955%; Component 5 = 4.372%; Component 6 = 3.837%; and Component 7 = 3.592% which accumulatively accounts for 73.95% of project management skills.

Critical assessment of the latent correlations amongst the variables under each component suggests the following explanation for each component: *Component 1* – skills related to work scheduling and coordination; *Component 2* – communication, risk, safety, and stakeholder management skills; *Component 3* – quality assurance skills; *Component 4* – managerial skills; *Component 5* – forecasting scope and duration of outage skills; *Component 6* – implementation of processes and time management skills; and *Component 7* – technical/engineering skills and experience pertaining to the outage and local site knowledge.

[Insert Table 4]

5. Discussion

The EFA revealed a clustering of the project management skills items into seven components (i.e., "skills related to working scheduling and coordination"; "communication, risk, safety and stakeholder management skills"; "quality assurance skills"; "managerial skills"; "forecasting scope and duration of outage skills"; "implementation of processes and time management skills"; and "technical/engineering skills and experience pertaining to the outage and local site knowledge"). In discussing the results, much effort was given to pattern matching instead of discussing the individual items under each main component. This thread became necessary because of the need to avoid the repetition of issues that have already been presented and discussed in the conceptual underpinning of this study.

The component, "*skills related to work scheduling and coordination*", explained by eight variables/skills items, is observed to be the most important project management skills component, accounting for 37.901% of the variance in project management skills important for major maintenance projects in the energy sector. A project schedule is a timetable that shows the start and end date of all project tasks, how the tasks relate to each other, and how team members or other resources are responsible for the delivery (Australian Institute of Project Management, 2021). Project coordination focuses on the daily tasks required to keep a project running smoothly. Scheduling and coordination skills are essential for maintenance projects in all sectors, including the energy sector. With scheduling, the project manager must demonstrate his skills by outlining the time needed for the required tasks, establishing milestones to be met to complete the project on time, and allocating resources across the tasks. The scheduling can be good; however, the project may fall behind schedule without appropriate coordination. Hence, during the management of maintenance projects, the project manager must unleash his coordinating skills by streamlining communication with stakeholders and team members, unblocking project team members, keeping the work moving, monitoring the project timeline, and ensuring that the work is completed on schedule, tracking the project budget and managing cost, and ensuring project information is easily accessible.

The component "*communication, risk, safety, and stakeholder management skills*", as explained by six variables/skills items, was observed as the second most important project management skills component, accounting for 11.789% of the variance in project management skills important for major maintenance projects in the energy sector. As can be seen in Table 4, there are six variables identified under this component Good communication keeps stakeholders and project teams motivated (PMI, 2013). Unfortunately, true communication inside and outside the enterprise walls remains a rare commodity, much of which comes down to a fundamental difficulty in communicating with the appropriate clarity and detail (PMI, 2013). Communication is an information transfer that is essentially one-way, i.e., from a sender to a receiver. It is important in undertaking every project because it seeks to create awareness, engages individuals with the message, and provides the needed information required for further action on the receiver's part. Sending out information regarding risks associated with a project, safety issues, stakeholder management issues, etc., are all done via communication. Hence, this is an important project management skill that professionals working on major maintenance projects in every sector, including energy, must possess. An energy manager, be it maintenance or otherwise, is involved in selling energy management as an activity at different levels (e.g., senior management, budget holders, plant and premises managers, and the general staff). Hence, engaging the attention of each of these groups motivates them to follow the advice and adopt better practices. In addition to being able to sell themselves in terms of their capabilities, the findings of this study have shown that the project manager who is involved in major maintenance projects in the energy sector must be able to resolve conflicts when they arise, effectively manage stakeholders, make decisions, manage and analyze risks, opportunities and other issues, and manage safety during the maintenance works.

With the huge increase in energy demands worldwide, most energy companies have realized the need to use proper project maintenance engineers to ensure that the energy flow is not interrupted. The component labeled "*quality assurance skills*" was explained by five variables/skills items and was identified as the third most important project management skills component, accounting for 7.504% of the variance in project management skills important for major maintenance projects in the energy sector. Taking a look at Table 4, one may notice that there are five variables within this component. In the views of Alamri et al. (2022), maintenance management involves planning, organizing, implementing, monitoring, and controlling to sustain a certain level of availability, value, and reliability of the system and its components and its ability to operate to a certain standard level of quality. This implies that the project maintenance engineers' work may involve checking, repairing, and servicing machinery, equipment, systems, and infrastructure. In all these works, quality must be assured, implying the need for quality assurance skills in maintenance projects. The term quality assurance ensures that the product developed meets quality standards set by the organization before it is launched into the market (Rodriguez, 2021). The findings from this study have revealed that the project maintenance manager in the energy sector must possess certain quality assurance skills if the quality of the maintenance project must be assured for clients to be satisfied. These skills were identified to include being able to: set standards and manage them, identify requirements for and ensure compliance with relevant regulations and procedures, manage quality, and establish, maintain and work within governance rules, frameworks and arrangements.

The fourth most important project management skills component accounted for 4.955% of the variance in project management skills important for major maintenance projects in the energy sector. This component was labeled as "*managerial skills*" and explained by four variables/skills items. A project maintenance manager must be able to manage their workforce to ensure that the maintenance works are successfully undertaken. This means that such a manager must possess 'people management skills'. People management skills are also known as soft skills. They are skills needed to treat, communicate with, and lead your people as a manager for maximum results (Lewis and Boucher, 2012). A manager who possesses these skills can be the difference between a team that is frustrated, confused, and underperforming and a team that is productive, motivated, and engaged. This study revealed that a project manager who oversees maintenance projects in the energy sector must possess four peculiar people skills. They must possess team building and management skills, good motivational and negotiation skills, and be able to provide their subordinates with accurate information. The team-building skills will help the project manager form interactive, supportive, and high-functioning teams for the maintenance project. Motivational skills have the potential to elicit a desired behaviour or response from a stakeholder. With good motivational skills, the project manager must increase their chance of getting positive results from customers, subordinates, upper management, and team members. With good negotiation skills, the project manager who oversees a maintenance project in the energy sector could develop a more solid relationship with stakeholders and have a better relationship with customers, which could guarantee a more positive work environment.

The component "*forecasting scope and duration of outage skills*" was explained by three variables/skills items and was identified as the fifth most important project management skills component, accounting for 4.372% of the variance in project management skills important for major maintenance projects in the energy sector. In project management, forecasting involves making predictions, guesses, or assumptions about the possible outcomes of a project. Forecasting is important because it reduces project risks and increases the chances of project success. According to Burger (2021), forecasting before the start of a project ensures one's preparedness to enter the project and be ready to respond when the unexpected happens. This implies that the project manager must possess forecasting and other skills. The findings of this study have revealed that the most important forecasting skills a project manager overseeing major maintenance projects in the energy sector must possess include the ability to forecast scope and time and assess and justify stakeholders. According to the Project Management Body of Knowledge (PMBOK), a project scope must include all the work required and only the work needed for successful completion (Project Management Institute, 2017). The project manager involved in major maintenance in the energy sector must possess skills that could enable them to make specific predictions on the possible outcome of the maintenance works. Hence, this scope forecasting skill should be able to assist the project manager in ensuring that all the maintenance works required and only the maintenance works required are carried out to ensure the successful completion of the maintenance project. The project manager must possess forecasting duration skills to periodically update the project schedule to keep the project end dates current. These forecasting skills, together with being able to assess and justify stakeholder requirements, could ensure the successful maintenance of projects in the energy sector.

The component "*implementation of processes and time management skills*" was also explained by three variables/skills items and was observed as the sixth most important project management skills component, accounting for 3.837% of the variance in project management skills important for major maintenance projects in the energy sector. Industries implement maintenance schemes based on equipment manufacturers' recommendations that may not be able to generate positive changes throughout the lifecycle of an asset (Patino-Rodriguez and Carazas, 2018). Organizational management systems should aid the decision-making process and include some level of forecasting, acknowledging the inevitability of occasional failure. Patino-Rodriguez and Carazas (2018) iterated that effective management requires systems and tools to predict the reliability of production systems. To predict failures or defects with a high degree of certainty, the operator can manage the logistics and resources necessary to make interventions with the least impact on production (Besnard and Bertling, 2010; Herrera et al., 2009). Above all, it is necessary to identify the goals of maintenance management within the organization, and these goals must fully align with those of the corporate management. Hence, strategically framing maintenance decisions within the corporate mission is advisable. To do this effectively, this study has revealed that the project manager who oversees a major maintenance project in the energy sector must possess process implementation and time management skills. With process implementation skills, the project manager must strategically assist the organization in adopting new project maintenance procedures.

"*Technical/engineering skills and experience pertaining to outage and local site knowledge*" was identified as the seventh component. It was also explained by three variables/skills items and accounted for 3.592% of the variance in project management skills important for major maintenance projects in the energy sector. Robert and Goodwin (1992) postulated that it is increasingly common to find non-engineers managing projects with substantial engineering components like major infrastructure works. Engineers today require a holistic understanding of product and process conceptualization, design, implementation, and operation (Kans, 2021).

Emetere et al. (2021) state that most countries experience power crises because of inadequate maintenance. This inadequate maintenance may arise because most of the energy sector's industries may not be able to attract proper talents into the maintenance engineering profession. Technical skills are specialized knowledge and expertise required to perform specific tasks and use specific tools and programs in real-world situations. These skills are required of professionals in every sector. The findings of this study have revealed that for a project manager to oversee major maintenance projects in the energy sector successfully, that project manager must possess the technical experience and engineering skills in this sector. The objectives of any maintenance strategy include a complete balance between capacity, efficiency, availability, reliability, and maintenance costs (Zhao et al., 2022), appropriate to the industrial and economic environment in which the particular plant operates. This further implies that the project manager must also possess some local site-based knowledge, especially regarding the maintenance of power plants. In sum, a project manager who manages major projects in the energy sector must possess the required technical and engineering skills like observation, estimation, planning, and execution; operation and maintenance information storage and retrieval; cost accounting; and evaluation.

Conclusions

In this study, a careful investigation into the key project management (PM) skills required to successfully manage major maintenance projects within the UK energy industry was undertaken. To do this, firstly, forty-six potential skill sets were obtained from the related literature. Then, the respondents were required to indicate the importance of these skills for successfully delivering maintenance projects in the energy sector. Data obtained from the survey were analyzed using One sample t-test and exploratory factor analysis. Results from the One sample t-test revealed that the top twelve skills (i.e., those in the top third of important skills) were in the numerical order: Communication Skills (Written & Oral); Safety Management; Decision Making; Leadership; Identification of requirements for, and ensuring compliance with relevant regulations and procedures; Ability to manage and analyse risks, opportunities and other issues; Stakeholder Management; Setting standards and managing them; Technical Experience (including experience of major maintenance projects); Time management; Organisational skills; and Quality Management. Furthermore, the results from the EFA revealed that the identified skills could be grouped under seven broad critical skills. These are in the order: skills related to work scheduling and coordination; communication, risk, safety, and stakeholder management skills; quality assurance skills; people management skills; forecasting scope and duration of outage skills; implementation of processes and time management skills; and technical/engineering skills and experience pertaining to the outage and local site knowledge.

Overall, the study's outcome has empirically demonstrated that for project managers to successfully manage major maintenance projects in the energy sector, they must demonstrate certain critical skills. This study's theoretical and practical implications/contributions are enormous. Project managers with the needed and up-to-date skill sets can enhance their overall efficiency and effectiveness within the organizations they work with. Theoretically, this study bridges an important gap in the body of knowledge and further contributes to the state-of-the-art in the area. It provides a better understanding of the critical project management skills required to effectively deliver on major maintenance projects in the energy sector. The skills identified are peculiar to the energy sector, something which is limited in the literature. Practically, the results of this study could inform the energy sector businesses, stakeholders, and policymakers about which project management skills to critically develop to ensure that the sector achieves its desired outcome. The findings of this study would be beneficial for an employer to have at hand to ensure that they have the best personnel in place to deliver major maintenance projects on their assets. Employers can use the findings to ensure that they provide a robust training regime that empowers their employees to deliver major maintenance projects in line with their expectations successfully. Furthermore, aspiring major maintenance project managers can use these findings to ensure that they are concentrating on the most important areas of their professional development, thus ensuring that they are successfully meeting the demands of delivering a major maintenance project.

While the findings of this study provide valuable insights, the study's limitations ought to be acknowledged. Whilst this quantitative study has helped gain broad insights regarding the important skills, it is limited by the fact that quantitative studies may not be able to provide the underlying explanations for those insights. With this in mind, it is noted that the findings do not offer explanations as to why respondents provided the responses that were given. For example, it is difficult to conclusively determine why the respondents perceived certain skills as more or less important than others. Given the above limitation, there is an opportunity to conduct further research employing qualitative approaches (e.g., phenomenological study) to explore and address this area.

References

Alamri, W., Emar, W., Al-Omari, Z. and Alsour, M. (2022), "Maintenance management practices in electricity industry in Arab world: Case study in Jordan", Journal of Engineering Research and Reports, Vol. 22 No. 6, pp. 30-42.

Alberta Energy Regulator (2022), "Project lifecycle", available at: https://www.aer.ca/protecting-what-matters/holding-industry-accountable/how-does-the-aer-regulate-energy-development-in-alberta/project-life-cycle#:~:text=Every%20energy%20development%20project%E2%80%94no,construct%2C%20operate%2C%20and%20close., accessed 22/08/2022.

Albert, M., Balve, P. & Spang, K. (2017). Evaluation of project success: a structured literature review. *International Journal of Managing Projects in Business*, , 10(4), pp. 796-821.

Al-Turki, U., Salih, . D. & Bendaya, M. (2019). Trends in Turnaround Maintenance Planning: Literature Review. *Journal of Quality in Maintenance Engineering*, 25(2), pp. 253-271.

Andruşcă, M., Adam, M., Irimia, F.D. and Baraboi, A. (2012), "Prioritization of maintenance activities from an electricity company", In Procs: 13th International Conference on Optimization of Electrical and Electronic Equipment (OPTIM), 24-26 May 2012, Brasov, Romania.

Armaroli, N. & Balzani, V. (2011). *Energy for a sustainable world; from the oil age to a sun-powered future*, Germany: Weinheim.

Association for Project Management (2015). *APM Competence Framework*, s.l.: 2nd.

Australian Institute of Project Management (2021), What is a project schedule?, available at: https://www.aipm.com.au/blog/what-is-a-project-schedule, accessed 12/06/2022.

Ben-Daya, M., Kumar, U. & Murthy, D. P. (2016). *Introduction to Maintenance Engineering: Modeling, Optimisation, and Management.* 1st ed. West Sussex: John Wiley & Sons, Ltd.

Berssaneti, F.T. and Carvalho, M.M. (2015), "Identification of variables that impact project success in Brazilian companies", International Journal of Project Management, Vol. 33 (2015), pp. 638-649.

Besnard, F. and Bertling, L. (2010), An Approach for Condition-Based Maintenance Optimisation Applied to Wind Turbine Blades. IEEE Transactions on Sustainable Energy, Vol. 1 No. 2, pp. 77-83

BS EN 60300-3-11. Dependability management — Part 3-11: Applicationguide — Reliability centred maintenance; 2009

BS EN 13306 (2010). Glossary of Terms Used in Terotechnology.

Cabinet Office (2019). *Public Summary of Sector Security and Resilience Plans*, London: Crown Copyright.

Chang, A., Chih, Y.-Y., Chew, E. & Pisarski, A. (2013). Reconceptualising mega project success in Australian defence: recognising the importance of value co-creation. *International Journal of Project Management* , 31(8), pp. 1139-1153.

Cirella, G.T. and Pawłowska, B. (2021), "Advancements in the Energy Sector and the Socioeconomic Development Nexus", Energies 2021, 14, 8078. https://doi.org/10.3390/en14238078

Committee on Climate Change (2019). *Net Zero: The UK's contribution to stopping global warming*, s.l.: s.n.

Creswell, J.W. and Creswell, J. D. (2018) Research design: qualitative, quantitative, and mixed method approaches. 3rd ed. California: Sage Publications.

Csereklyei, Z., Stern, D.I. (2015), "Global energy use: decoupling or convergence"? Energy Economics. 51, 633–641. doi:http://dx.doi.org/10.1016/j.eneco.2015.08.029.

Department for Business, Energy & Industry Strategy (2021). *Energy Trends, UK, October to December 2020 and 2020*, London: s.n

de Winter, J.C.F., Dodou, D. and Wieringa, P.A. (2009), "Exploratory factor analysis with small sample size", Multivariate Behavioural Research, Vol. 44 No. 2, pp. 147-181.

Duarte, A.L.C.M. and Scarpin, M.R.S.S. (2022), "Maintenance practices and overall equipment effectiveness: testing the moderating effect of training", Journal of Qulity in Maintenance, ahead-of-print, DOI: 10.1108/JQME-04-2021-0033.

Duffuaa, S. O. & Daya, M. B. (2004). Turnaround Maintenance in Petrochemical Industry: practices and suggested improvements. *Journal of Quality in Maintenance Engineering,* 10(3), p. 184.

EDF Energy, 2021. *About Hinkley Point C EDF.* [Online] Available at: https://www.edfenergy.com/energy/nuclear-new-build-projects/hinkley-point-c/about
[Accessed June 2021].

Elmabrouk, O.M. and Fardous, A. (2012), "Crashing project activities using linear programming techniques", Proceedings of the 2012 International Conference on Industrial Engineering and Operations Management, Istanbul, Turkey July 3-6, 2012.

Emeteri, M.E., Agubo, O. and Chikwendu, L. (2021), "Erratic electric power challenges in Africa and the way forward via the adoption of human biogas resources", Energy Exploration and Exploitation, Vol. 39 No. 4, pp. 1349-1377.

Energy UK (2020). *Energy in the UK 2020,* London: Energy-uk.org.uk.

Ertl, B. (2015). *Applying PMBOK to Shutdowns, Turnarounds and Outages.* [Online] Available at: http://www.plant-maintenance.com/articles/ApplyingPMBOKtoShutdowns.shtml
[Accessed 03 June 2020].

Fellows, R. and Liu, A. (2015) Research methods for construction, 4 edn. Chichester: Wiley Blackwell Publishing.

Field, A.P. (2013), Discovering Statistics Using IBM SPSS Statistic, 4th ed., Sage Publications, Thousand Oaks, California.

Global Energy Perspectives (2022). Available at: https://www.mckinsey.com/~/media/McKinsey/Industries/Oil%20and%20Gas/Our%20Insights/Global%20Energy%20Perspective%202022/Global-Energy-Perspective-2022-Executive-Summary.pdf, accessed 27/08/2022.

Grant, M.J. and Booth, A. (2009), "A Typology of Reviews: An Analysis of 14 Review Types and Associated Methodologies", Health Information & Libraries Journal, 26, 91-108.

Herrera, I.A., Nordskag, A.O., Myhre, G. and Halvorsen, K. (2009), Aviation safety and maintenance under major organisational changes, investigating non-existing accidents. Accident; Analysis and Prevention, Vol. 41 No. 6, pp.1155-1163

Hlophe, S. C. & Visser, J. K. (2018). Risk Management during Outage Projects at Power Plants. *South African Journal of Industrial Engineering,* November, 29(3), pp. 82-91.

HM Treasury (2020). *Net Zer Review: Interim Report,* London: Crown Copyright.

Iheukwumere-Esotu, L. O., and Yunusa-Kaltungo, A. (2021). Knowledge criticality assessment and codification framework for major maintenance activities: A case study of cement rotary kiln plant. Sustainability, 13(9), 4619.

Iheukwumere-Esotu, L. O., and Yunusa Kaltungo, A. (2020a). Assessment of barriers to knowledge and experience transfer in major maintenance activities. Energies, 13(7), 1721.

Iheukwumere-Esotu, L., and Yunusa-Kaltungo, A. (2020b). A Systematic Analysis of Research Based Evidences of Major Overhauls, Outages, Shutdowns, Turnarounds (MoOSTs) Management. In International Conference on Maintenance Engineering (pp. 627-635). Springer, Cham.

Iheukwumere-Esotu, L. O. & Kaltungo, A. Y. (2020c). Assessment of Barriers to Knowledge and Experience Transfer in Major Maintenance Activities. *Energies 2020*, 13(7), pp. 1 - 24.

Institute For Government (2020). *UK Net Zero Target*, s.l.: s.n.

Kans, M. (2021), "A study of maintenance-related education in Swedish engineering programmes", Education Science, Vol. 11 No. 9, pp. 535.

Khasanah, R., Jamasri & Yuniarto, H. A. (2019). *Evaluation of turnaround maintenance practice effects in the process industry.* Indonesia, IOP Publishing.

Kister, T. C. & Hawkins, B. (2006). *Maintenance planning and scheduling : streamline your organisation for a lean environment.* New York: Elsevier Butterworth-Heinmann.

Kyriazos, T. (2018), "Applied psychometrics: Sample size and sample power considerations in Factor Analysis (EFA, CFA) and SEM in general", Psychology, Vol. 9 No. 8, pp. 2207-2230.

Laila, K. (2015), "Suggested guidelines for integrating maintenance considerations into the lifecycle of the building", Journal of Construction, Vol. 8 No. 1, pp. 1-9.

Lenahan, T. (2005). *Turnaround, Shutdown and Outage Management: Effective Planning and Step-By-Step Execution of Planned Maintenance Operations.* 1st ed. Oxford: Butterworth-Heinemann.

Lewis, Y. R. & Boucher, L. (2012). PM—people management or project management? Paper presented at PMI® Global Congress 2012—North America, Vancouver, British Columbia, Canada. Newtown Square, PA: Project Management Institute.

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

Lyu, W. and Liu, J. (2021), "Soft skills, hard skills: What matters most? Evidence from job postings", Vol. 300 (2021), pp. 117307.

McLeod, L., Doolin, B. & MacDonell, S. (2012). A perspective-based understanding of project success. *Project Management Journal,* 43(5), pp. 68 - 88.

Mahamadu, A. M., Manu, P., Booth, C., Olomolaiye, P., Coker, A., Ibrahim, A., & Lamond, J. (2018). Infrastructure procurement skills gap amongst procurement personnel in Nigeria's public sector. *Journal of Engineering, Design and Technology,* 16(1), pp. 2-24.

Manu, P., Asiedu, R.O., Mahamadu, A.-M., Olomolaiye, P.O., Booth, C., Manu, E., Ajayi, S. and Agyekum, K. (2020), "Contribution of procurement capacity of public agencies to attainment of procurement objectives in infrastructure procurement, Engineering, Construction and Architectural Management, DOI: 10.1108/ECAM-05-2020-0375.

Moynihan, G.P., Bowers, J.H., Fonseca, D.J. and Ray, P.S. (2002), "A knowledge-based approach to maintenance project planning", Expert Systems, Vol. 19 No. 2, pp. 88-98.

Mtembi, T. & Kanakana, M. G., 2015. *Project Management Approach for Turbine Maintenance in Power Utility Plants: The Case of a South African Maintenance Company.* Pretoria: Institue of Electrical and Electronics Engineer (IEEE).

National Cyber Security Centre (2020). *CNI Hub.* [Online] Available at: https://www.ncsc.gov.uk/section/private-sector-cni/cni [Accessed 20 November 2020].

National Grid ESO, 2020. *Future Energy Scenarios.* [Online] Available at: https://www.nationalgrideso.com/document/173821/download [Accessed May 2021].

Ngo, J. and Hwang, B.-G. (2022), "Critical project management knowledge and skills for managing projects with smart technologies", Journal of Management in Engineering, Vol. 38 No. 6, pp. 05022013.

Obiajunwa, C. C. (2013). Skills for the management of turnaround maintenance projects. *Journal of Quality in Maintenance Engineering*, 19(1), pp. 61-73.

Odusami, K. (2002). Perceptions of Construction Professionals Concerning Important Skills of Effective Project Leaders. *Journal of Management in Engineering*, April, 18(2), pp. 61-67.

Ofgem (2019). *State of the Energy Market 2019 - Ofgem.* [Online] Available at: https://www.ofgem.gov.uk/publications-and-updates/state-energy-market-2019 [Accessed 01 May 2021].

Olsen, T., 2018. Turnarounds: Strategic Opportunities to Improve. *AMERICAN INSTITUTE OF CHEMICAL ENGINEERS,* August.pp. 46 - 50.

Osborne, J.W. and Costello, A.B. (2004), "Sample size and subject to item ratio in principal component analysis", Practical Assessment, Research and Evaluation, Vol. 9 No. 11, pp. 1-9.

Pallant, J. (2016), SPSS Survival Manual: A step by step guide to data analysis using IBM SPSS. Open University Press, McGraw-Hill Education, *McGraw Hill House*, Berkshire, UK.

Patino-Rodriguez, C.E. and Carazas, F.J.G. (2018), "Maintenance and asset life cycle reliability for reliability systems". In: Reliability and Maintenance- An overview of cases, IntechOpen, available at: https://www.intechopen.com/chapters/67110, accessed 10/6/2022.

Peters M, Marnie C, Tricco A, et al. Updated Methodological Guidance for the Conduct of Scoping Reviews. *JBI Evidence Implementation*, Vol. 19, pp. 3-10

Project Management Institute, PMI, (2017), A guide to the Project Management Body of Knowledge, PMBOK, Sixth Edition.

PMI (2013), "Communication: The message is clear", available at: https://www.pmi.org/learning/library/communication-11189, accessed 10/06/2022.

Pokharel, S. & Jiao, . J. (2008). Turn-around maintenance management in a processing industry: A Case Study. *Journal of Quality in Maintenance Engineering,* 14(2), pp. 109-122.

Power Technology (2021). *Hinkley Point C Nuclear Power Station - Power Technology | Energy News and Market Analysis.* [Online] Available at: https://www.power-technology.com/projects/hinkley-point-c-nuclear-power-station/
[Accessed 20 June 2021].

Rinaldi, G.; Thies, P.R.; Johanning, L. Current Status and Future Trends in the Operation and Maintenance of OffshoreWind Turbines: A Review. Energies **2021**, 14, 2484. https://doi.org/10.3390/en14092484.

Robert, S. and Goodwin, C. (1992), "Skills required of effective project managers", Journal of Management in Engineering, Vol. 9 No. 3, pp. 217-226.

Rodriguez, D. (2021), "Roles and responsibilities of a quality assurance manager", available at: https://www.invensislearning.com/blog/quality-assurance-manager-roles-and-responsibilites/, accessed 10/06/2022.

Serrador, P. a. T. R. (2015). The relationship between project success and project efficiency. *Project Management Journal,*, 46(1), pp. 30-39..

Smith, R. (2001). Planning and Scheduling Outages. In: R. K. Mobley, ed. *Plant Engineer's Handbook.* s.l.:Butterworth-Heinemann.

van der Westhyssen, J. (2014). Optimizing value extraction from turnarounds. *Procedia Engineering*, Volume 83, p. 477 – 483.

World Nuclear News (2021). *Hinkley Point C delayed until at least 2026 : Corporate - World Nuclear News.* [Online] Available at: https://world-nuclear-news.org/Articles/Hinkley-Point-C-delayed-until-at-least-2026
[Accessed 20 June 2021].

Zhao, J., Gao, C. and Tang, T. (2022), "A review of sustainable maitenance strategies for single component and multicomponent equipment", Sustainability, Vol. 14 No. 5, pp. 2992.

Table 1 - Literature Review – Details of Skills Identified

Skills	Literature Sources										
	(Ngo and Hwang, 2022)	(Al-Turki, et al., 2019)	(PMI, 2017)	(Ben-Daya, et al., 2016)	(Association for Project Management, 2015)	(Obiajunwa, 2013)	(Pokharel & Jiao, 2008)	(Duffuaa & Daya, 2004)	(Odusami, 2002)	(Smith, 2001)	(Robert and Goodwin, 1992)
Leadership		✓	✓		✓	✓			✓		✓
Team Building and Management					✓				✓		✓
Motivational Skills			✓			✓			✓		
Conflict Resolution	✓		✓		✓	✓		✓	✓		
Communication Skills (Oral and Written)	✓	✓	✓	✓	✓			✓	✓		
Stakeholder management			✓		✓		✓		✓		
Negotiation Skills		✓	✓			✓			✓		
Decision Making Skills	✓		✓	✓		✓			✓		
Risk, Opportunity and Issues Management and Analysis		✓	✓		✓				✓		
Supervisory Skills						✓					
Entrepreneurial Skills									✓		

Skills	Literature Sources										
	(Ngo and Hwang, 2022)	(Al-Turki, et al., 2019)	(PMI, 2017)	(Ben-Daya, et al., 2016)	(Association for Project Management, 2015)	(Obiajunwa, 2013)	(Pokharel & Jiao, 2008)	(Duffuaa & Daya, 2004)	(Odusami, 2002)	(Smith, 2001)	(Robert and Goodwin, 1992)
Application of ethics guidelines & Professionalism	✓				✓						
Compliance (Regulatory etc.)			✓		✓						
Organisational Skills	✓		✓	✓		✓			✓		✓
Time Management Skills						✓			✓	✓	
Delegation Skills									✓		
Forecasting Skills (Scope)						✓					✓
Forecasting Skills (Cost)		✓			✓			✓	✓	✓	✓
Forecasting Skills (Time estimation/duration)										✓	✓
Scope Management		✓		✓			✓			✓	✓
Generic Planning Skills	✓		✓	✓	✓		✓	✓	✓	✓	
Resource Management Skills		✓	✓	✓	✓	✓	✓		✓		✓
Work Scheduling Skills		✓	✓	✓				✓	✓	✓	

Skills	Literature Sources										
	(Ngo and Hwang, 2022)	(Al-Turki, et al., 2019)	(PMI, 2017)	(Ben-Daya, et al., 2016)	(Association for Project Management, 2015)	(Obiajunwa, 2013)	(Pokharel & Jiao, 2008)	(Duffuaa & Daya, 2004)	(Odusami, 2002)	(Smith, 2001)	(Robert and Goodwin, 1992)
Works Coordination Skills			✓	✓			✓	✓	✓	✓	✓
Schedule Management			✓		✓				✓		✓
Computer Literacy	✓					✓	✓		✓		
Technical Experience (including experience of Outages/Major Maintenance projects)	✓		✓			✓		✓	✓	✓	
Engineering Skills		✓		✓				✓			
Budget Management		✓	✓	✓	✓	✓		✓	✓	✓	
Safety Related Skills				✓		✓	✓	✓			
Establishing Goals				✓			✓		✓	✓	
Implementation of Actions				✓			✓				
Setting Standards and Managing them										✓	
Contract Management Skills			✓	✓	✓		✓	✓			
Local Site Based Knowledge				✓			✓	✓		✓	

Skills	Literature Sources										
	(Ngo and Hwang, 2022)	(Al-Turki, et al., 2019)	(PMI, 2017)	(Ben-Daya, et al., 2016)	(Association for Project Management, 2015)	(Obiajunwa, 2013)	(Pokharel & Jiao, 2008)	(Duffuaa & Daya, 2004)	(Odusami, 2002)	(Smith, 2001)	(Robert and Goodwin, 1992)
Quality Management				✓	✓		✓	✓	✓	✓	
Procurement; Ordering Spares & Materials		✓		✓	✓	✓	✓	✓			
Assess and justify stakeholders' requirements	✓				✓					✓	
Commissioning plant and equipment, including handover					✓						
Establish, maintain and work within governance rules, frameworks and arrangements					✓					✓	
Conducts Reviews of project progress and impact of changes				✓	✓			✓			
Gains independent assurance that information received is accurate					✓						
Prepare and gain approval of business case					✓					✓	

Skills	Literature Sources										
	(Ngo and Hwang, 2022)	(Al-Turki, et al., 2019)	(PMI, 2017)	(Ben-Daya, et al., 2016)	(Association for Project Management, 2015)	(Obiajunwa, 2013)	(Pokharel & Jiao, 2008)	(Duffuaa & Daya, 2004)	(Odusami, 2002)	(Smith, 2001)	(Robert and Goodwin, 1992)
Identification of development and improvement opportunities (including mentoring, coaching etc.)					✓						
Specification Writing										✓	

Table 2: Background information on respondents

Characteristic	Frequency	Percentage
Professional role undertaken within most recent planned major maintenance project		
Engineer	22	35.5
Planner/Scheduler	6	9.7
Manager/Team Leader	11	17.7
Skilled Tradesperson	4	6.5
Health and Safety Officer or Advisor	1	1.6
Technical Authority/Advisor	5	8.1
Quality Assurance	4	6.5
Senior Manager	5	8.1
Other	4	6.5
Position in organisation		
Lower (e.g. Junior Staff)	10	16.1
Middle (e.g. Senior Staff/Team Leader)	43	69.4
High (e.g. Department/Unit Head)	4	6.5
Top (e.g. Director/Executive)	3	4.8
Other	2	3.2
Frequency of involvement in planned major maintenance projects		
Frequently - Typically once every 1 to 2 years	16	25.8
Occasionally - Typically once every 2 to 3 years	3	4.8
Rarely - Typically once every 3 to 4 years	1	1.6
Very Rarely - Typically only once every 4 to 5 years	1	1.6
Almost Never - Typically only once every 5 or more years	1	1.6
Regularly - At least once a year - sometimes more than once a year	40	64.5
Last involvement in a planned major maintenance project		
More than 5 years ago	3	4.8
More than 4 but less than 5 Years ago	1	1.6
More than 2 but less than 3 Years ago	2	3.2
More than 1 but less than 2 Years ago	3	4.8
Within the last 12 months	53	85.5
Professional body membership status		
Member of professional body	38	61.3
Working towards membership of professional body	7	11.3
Not working towards membership of professional body	17	27.4
Academic Qualification		
Secondary school qualification	1	1.6
Diploma	3	4.8
Higher national certificate/higher national diploma	16	25.8
Bachelor degree	16	25.8
Postgraduate Diploma	1	1.6
Master’s Degree	19	30.6
PhD degree	3	4.8
Other	3	4.8

Table 3 – 1 sample t-test of importance of skills

Skill	N	Mean	Rank by Mean	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)	Sig. (1-tailed)	Mean Difference	95% Confidence Interval of the Difference	
											Lower	Upper
Communication Skills (Written & Oral)	62	4.66	1	0.676	0.086	13.524	61	0.000	0.000	1.161	0.99	1.33
Safety management	62	4.65	2	0.749	0.095	12.044	61	0.000	0.000	1.145	0.96	1.34
Decision Making	62	4.55	3	0.670	0.085	12.327	61	0.000	0.000	1.048	0.88	1.22
Leadership	62	4.42	4	0.714	0.091	10.139	61	0.000	0.000	0.919	0.74	1.10
Identification of requirements for, and ensuring compliance with relevant regulations and procedures	62	4.42	4	0.841	0.107	8.612	61	0.000	0.000	0.919	0.71	1.13
Ability to manage and analyse risks, opportunities and other issues	62	4.40	6	0.819	0.104	8.683	61	0.000	0.000	0.903	0.70	1.11
Stakeholder Management	62	4.34	7	0.848	0.108	7.786	61	0.000	0.000	0.839	0.62	1.05
Setting standards and managing them	62	4.29	8	0.876	0.111	7.107	61	0.000	0.000	0.790	0.57	1.01
Technical Experience (including experience of major maintenance projects)	62	4.23	9	0.818	0.104	6.985	61	0.000	0.000	0.726	0.52	0.93
Time management	62	4.21	10	0.832	0.106	6.712	61	0.000	0.000	0.710	0.50	0.92
Organisational skills	62	4.16	11	0.853	0.108	6.104	61	0.000	0.000	0.661	0.44	0.88
Quality management	62	4.10	12	1.020	0.129	4.609	61	0.000	0.000	0.597	0.34	0.86
Conduct reviews of project progress and impact of changes	62	4.08	13	0.893	0.113	5.122	61	0.000	0.000	0.581	0.35	0.81
Establish, maintain and work within governance rules, frameworks and arrangements	62	4.05	14	1.015	0.129	4.254	61	0.000	0.000	0.548	0.29	0.81
Team Building and Management	62	4.03	15	0.975	0.124	4.300	61	0.000	0.000	0.532	0.28	0.78
Scope Management	62	4.02	16	1.094	0.139	3.715	61	0.000	0.000	0.516	0.24	0.79
Conflict Resolution	62	4.00	17	0.992	0.126	3.970	61	0.000	0.000	0.500	0.25	0.75
Local site-based knowledge	62	4.00	17	0.887	0.113	4.438	61	0.000	0.000	0.500	0.27	0.73
Forecasting (Time Estimation/Duration)	62	3.98	19	1.016	0.129	3.750	61	0.000	0.000	0.484	0.23	0.74
Motivational Skills	62	3.97	20	0.923	0.117	3.991	61	0.000	0.000	0.468	0.23	0.70

Implementation of processes and actions to ensure goals are achieved	62	3.97	20	0.829	0.105	4.442	61	0.000	0.000	0.468	0.26	0.68
Generic planning skills	62	3.95	22	0.965	0.123	3.683	61	0.000	0.000	0.452	0.21	0.70
Resource Management	62	3.95	22	1.151	0.146	3.089	61	0.003	0.002	0.452	0.16	0.74
Forecasting (Scope)	62	3.94	24	0.990	0.126	3.465	61	0.001	0.000	0.435	0.18	0.69
Commissioning plant and equipment, including handover	62	3.92	25	1.135	0.144	2.909	61	0.005	0.003	0.419	0.13	0.71
Gains independent assurance that information is accurate	62	3.92	25	0.929	0.118	3.556	61	0.001	0.000	0.419	0.18	0.66
Work Coordination	62	3.90	27	1.003	0.127	3.164	61	0.002	0.001	0.403	0.15	0.66
Engineering Skills	62	3.85	28	1.006	0.128	2.778	61	0.007	0.004	0.355	0.10	0.61
Delegation	62	3.81	29	1.084	0.138	2.226	61	0.030	0.015	0.306	0.03	0.58
Schedule Management	62	3.81	29	1.128	0.143	2.138	61	0.037	0.018	0.306	0.02	0.59
Computer Literacy	62	3.81	29	0.938	0.119	2.572	61	0.013	0.006	0.306	0.07	0.54
Work Scheduling Skills	62	3.77	32	1.078	0.137	2.003	61	0.050	0.025	0.274	0.00	0.55
Contract management skills	62	3.77	32	1.137	0.144	1.899	61	0.062	0.031	0.274	-0.01	0.56
Ability to assess and justify stakeholder requirements	62	3.77	32	1.108	0.141	1.949	61	0.056	0.028	0.274	-0.01	0.56
Negotiation Skills	62	3.76	35	0.970	0.123	2.095	61	0.040	0.020	0.258	0.01	0.50
Supervisory Skills	62	3.74	36	1.070	0.136	1.780	61	0.080	0.040	0.242	-0.03	0.51
Establishing Goals	62	3.74	36	0.940	0.119	2.027	61	0.047	0.024	0.242	0.00	0.48
Application of ethics guidelines and professionalism	62	3.71	38	1.122	0.142	1.472	61	0.146	0.073	0.210	-0.08	0.49
Forecasting (Cost)	62	3.69	39	1.110	0.141	1.373	61	0.175	0.087	0.194	-0.09	0.48
Budget Management	62	3.65	40	1.103	0.140	1.036	61	0.304	0.152	0.145	-0.13	0.43
Identification and development of improvement opportunities (including mentoring, coaching etc.)	62	3.60	41	1.108	0.141	0.688	61	0.494	0.247	0.097	-0.18	0.38
Specification writing	62	3.55	42	1.263	0.160	0.302	61	0.764	0.382	0.048	-0.27	0.37
Prepare and gain approval of business case	62	3.52	43	1.302	0.165	0.098	61	0.923	0.461	0.016	-0.31	0.35
Procurement, ordering spares and materials	62	3.42	44	1.167	0.148	-0.544	61	0.588	0.294	-0.081	-0.38	0.22
Entrepreneurial Skills	62	2.87	45	1.123	0.143	-4.409	61	0.000	0.000	-0.629	-0.91	-0.34

Table 4: EFA results

Project management skills	Communalities after extraction	Component of project management skills						
		1	2	3	4	5	6	7
Supervisory Skills	0.749	0.543						
Generic planning skills	0.767	0.728						
Scope Management	0.772	0.722						
Resource Management	0.790	0.752						
Work Scheduling Skills	0.812	0.846						
Work Coordination	0.823	0.857						
Commissioning plant and equipment, including handover	0.711	0.747						
Schedule Management	0.812	0.770						
Conflict Resolution	0.765		0.562					
Communication Skills (Written & Oral)	0.755		0.757					
Stakeholder Management	0.778		0.610					
Decision Making	0.806		0.601					
Ability to manage and analyse risks, opportunities and other issues	0.781		0.743					
Safety management	0.718		0.672					
Setting standards and managing them	0.726			0.563				
Contract management skills	0.766			0.622				
Identification of requirements for, and ensuring compliance with relevant regulations and procedures	0.706			0.650				
Quality management	0.834			0.760				
Establish, maintain and work within governance rules, frameworks and arrangements	0.795			0.709				
Team Building and Management	0.755				0.689			
Motivational Skills	0.795				0.724			
Negotiation Skills	0.772				0.643			

Gains independent assurance that information is accurate	0.703				0.645			
Forecasting (Scope)	0.854					0.751		
Forecasting (Time Estimation/Duration)	0.806					0.741		
Ability to assess and justify stakeholder requirements	0.751					0.714		
Establishing Goals	0.758						0.567	
Implementation of processes and actions to ensure goals are achieved	0.795						0.740	
Time management	0.769						0.663	
Technical Experience (including experience of outages)	0.804							0.745
Engineering Skills	0.823							0.652
Local site based knowledge	0.755							0.716
Eigen value		14.023	4.362	2.776	1.833	1.618	1.420	1.329
Variance explained		37.901	11.789	7.504	4.955	4.372	3.837	3.592
Cronbach alpha		0.918	0.864	0.868	0.831	0.879	0.829	0.759

Notes:

Extraction method = principal component analysis

Rotation method = varimax rotation

Kaiser-Meyer-Olkin Measure of Sampling Adequacy = 0.75

Bartlett's Test of Sphericity: : Chi-Square = 2017.525 (df =666), $p < 0.001$

The factor loadings less than 0.5 were suppressed.

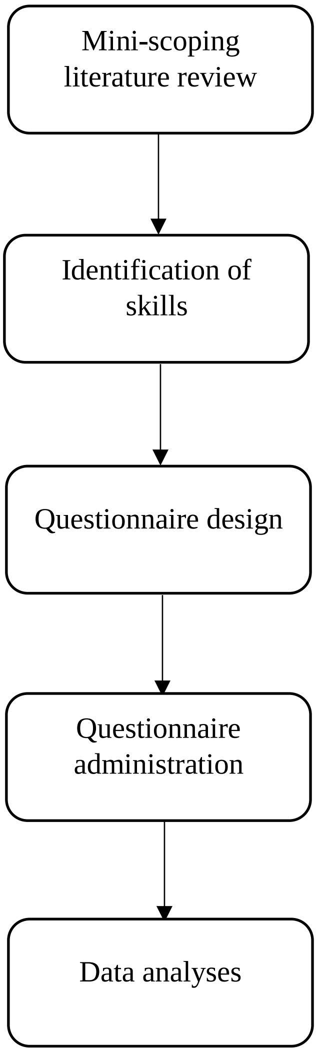

Figure 1: Overview of the research process