Utilisation of Risk Management, Project Management Tools and Teamwork for the Execution of Turnaround Maintenance Activities

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Abstract: This study is based on using management tools such as risk management, project management tools and teamwork in Turnaround Maintenance Activities (TMA) in a typical petrochemical and refinery industry in Nigeria, one of the notable oil-producing developing nations. To achieve the broad objective of the study, a structured questionnaire was developed based on three sub-hypotheses on the significance of the management tools under study in TMA in the petrochemical and refinery industry. The respondents consisted of carefully sampled 341 workers at a refining and petrochemical company, ranging from the Maintenance department, Engineering and Technical Services department, Health Services and Environment department, Supply Chain Management department, as well as contractors. Using inferential statistics and Pearson correlation analysis, the sub-hypotheses were analysed. The results of the study showed that the management tools considered have a significant relation with TMA with R-values of 0.617, 0.742, and 0.714 for the relationship of TMA with risk management, project management tools, and teamwork, respectively. Furthermore, the study's findings showed that most respondents strongly agree that the successful TMA implementation in the petrochemical and refinery industry is dependent on good risk management practices such as risk survey, quantification, mitigation, and leadership collaboration (p-value = 0.01), use of project management tools encompassing decomposition, critical path analysis, visualisation, accountability, and performance matrices (p-value = 0.002), and adequate integration of teamwork to ensure transparency, synchronisation, equity, and

collaboration (p-value = 0.002). The study concluded by recommending continuous application of these management tools and many more to ensure effective TMA in the industry.

Keywords: Turnaround Maintenance Activities (TMA), Petrochemical and refinery industry, Risk management, Project management, teamwork

الاستفادة من إدارة المخاطر وأدوات إدارة المشاريع والعمل الجماعي لتنفيذ أنشطة الصيانة الشاملة

الملخـــص: تعتمـد هـذه الدراسـة علـى اسـتخدام أدوات الإدارة مثـل إدارة المخـاطر وأدوات إدارة المشـاريع والعمـل الجمـاعي فـي أنشـطة الصـيانة الشـاملة (TMA) فـي صـناعة البتروكيماويـات ومصـافي التكريـر النموذجيـة فـي نيجيريـا، وهـي إحـدى الـدول الناميـة البـارزة المنتجـة للـنفط. ولتحقيـق الهـدف العـام للدراسـة، تـم تطـوير اسـتبيان مـنظم يعتمـد علـى ثـلاث فرضـيات فرعيـة حـول أهميـة أدوات الإدارة قيـد الدراسـة فـي TMA فـي صـناعة البتروكيماويـات والمصـافي. تـم اختيـار المشـاركين بعنايـة مـن 341 عـاملاً فـي إحـدى شـركات التكريـر والبتروكيماويـات، بـدءًا مـن قسـم الصـيانة، وقسـم الخـدمات الهندسـية والفنيـة، وقسـم الخـدمات الصـحية والبيئـة، وقسـم إدارة سلسـلة التوريـد، بالإضـافة إلـى المقـاولين. وباسـتخدام الإحصـاء الاسـتدلالي وتحليـل ارتبـاط بيرسـون، تـم تحليـل الفرضـيات الفرعيـة. أظهـرت نتـائج الدراسـة أن أدوات الإدارة المدروسـة لهـا علاقـة معنويـة بـ TMA بقيم R تبلـغ 0.617 و0.742 و0.714 لعلاقـة TMAبـإدارة المخـاطر وأدوات إدارة المشـاريع والعمـل الجمـاعي علـى التـوالي. عـلاوة علـى ذلـك، أظهـرت نتـائج الدراسـة أن معظـم المشـاركين يوافقـون بشـدة علـى أن التنفيـذ النـاجح للتحليـل الحـراري الميكـانيكي (TMA) فـي صـناعة البتروكيماويـات ومصـافي التكريـر يعتمـد علـى ممارسـات إدارة المخـاطر الجيـدة مثـل مسـح المخـاطر، والقيـاس الكمـي، والتخفيـف، وتعـاون القيـادة (القيمـة الاحتماليـة = 0.01)، والاسـتخدام لأدوات إدارة المشـروع التـي تشـمل التحليـل وتحليـل المسـار الحـرج والتصـور والمسـاءلة ومصـفوفات الأداء (القيمـة الاحتماليـة = 0.002)، والتكامـل المناسـب للعمـل الجمـاعي لضـمان الشـفافية والتـزامن والإنصـاف والتعـاون (القيمـة الاحتماليـة = 0.002). واختتمـت الدراسـة بالتوصية بالتطبيق المستمر لأدوات الإدارة هذه وغيرها الكثير لضمان في الصناعة.TMAفعالية

1.Introduction

Maintenance activities (MA) are distinctive and complicated undertakings frequently carried out on constrained timeframes [1]. MA operations demand many personnel who carry out their duties in crowded spaces. However, MA initiatives are crucial to maintaining steady production levels because they increase process plant dependability, lower the cost of corrective maintenance, and boost resource management effectiveness [2]. The degree to which MA operations are correctly carried out affects the company's general performance [3]. Due to the complexity and intensity of MA projects, MA costs can reach millions of dollars, including lost income and maintenance expenses [1]. Such losses may significantly affect the profitability of petrochemical and refinery companies [4], [5].

Based on this fact, businesses must ensure that assets perform at their highest levels to achieve high corporate performance (such as increased earnings and sales). MA initiatives are among the most expensive and time-consuming projects in the process sector, according to Witteman et al. [1], due to cost overruns and scheduling delays, which are fairly common with MA projects. Numerous variables may be responsible for cost overruns, including deficient execution planning, productivity loss during MA execution, and scope modifications (caused by unforeseen mechanical issues) [6]. Defective execution planning, scope revisions, or low productivity—the latter brought on by a shortage of trained workers—are the main causes of schedule delays [4]. Organisations that do maintenance on time, on budget, and without surprises typically have a defined work process and follow it, according to Iheukwumere et al. [5]. A well-defined and standardised approach is essential for MA planning and administration. Managers may achieve this by adopting and putting into practice tried-and-true industry best practices.

The maintenance sub-sector now faces skilled worker attrition, which multiplies risks, raises the demand for best practices, and necessitates a new paradigm: process- and unit-specific knowledge transfer, according to research studies that have emphasised the rising need for adopting best practices [7], [8]. However, limited studies exist on the petrochemical and refinery industry's best practices for turnaround maintenance activity (TMA) planning and management. However, the building sector has produced several

planning best practices that TMA projects may use with some adjustments [9]–[12]. Specifically, the Nigerian petrochemical and refinery industries experience high and persistent production downtime, which usually results in completion extended scheduled time, costs above the budget and sometimes not conforming to the planned scope. The level of use of project management tools, risk management and teamwork in TMA is unknown in Nigeria and developing countries at large industries.

Hence, this study presents a case study that identifies and establishes the utilisation of risk management, project management tools and teamwork in executing TMA in the petrochemical and refinery industries. The study seeks to i) identify the level of usage of project management tools, risk management and teamwork in TMA and ii) determine the impacts of project management tools, risk management and teamwork on TMA success.

2.Literature Review

Petrochemical and refinery plants often perform major maintenance tasks during shutdowns and turnarounds. During a TMA, a routine maintenance event, plants are shut down to execute necessary maintenance work that must be carried out when the plant's facilities are offline [4]. Among these MAs are inspections, repairs, replacements, and overhauls. The business plan, conceptual development, work development, detailed planning, pre-turnaround work, turnaround execution, and post-turnaround stages are therefore included in the TMA phases [13]. Three different types of work are done during MA projects, and they include work on equipment that requires shutting down the entire plant, work that can be done while the plant or equipment is in operation, and work that fixes flaws that were discovered while operation but could not be fixed at the time [14].

MA operations support plant production consistency in the process sector, in which large-scale, intricate MA projects are the norm [15]. Petrochemical and refinery companies need to be able to perform MA tasks while adhering to the budget, deadline, and quality requirements [5]. Meeting those limits is challenging without solid and reliable methods for planning and managing MA initiatives.

To consider some related works on TMA of petrochemical industries, the study by AlHamouri et al. [6] researched the use of workforce planning for maintenance tasks, shutdowns, and turnarounds in petrochemical plants. The first section of the study focused on creating a customised version of Workforce Planning (WFP) that would suit MAs in the petrochemical sector using feedback from subject matter experts (SMEs). The study team was able to evaluate the current levels of MA execution planning and management and identify ineffective areas by monitoring its implementation. This research provides suggestions on how to execute MA while maximising planning procedures. Ghaithan [13] studied the optimisation model for TMA scheduling and operational planning of the oil and gas supply chain. The model integrated the hydrocarbon supply chain plants and jointly developed operation and maintenance schedules. A model with and without integration between operating and maintenance tasks was investigated. The obtained results demonstrated the significance of the suggested model, and the model's outcomes were encouraging. The model mandated that all hydrocarbon supply chain plants be kept operational during periods of low demand to prevent significant production losses, meet the majority of demand, and reduce lost sales as much as possible.

In similar industries, Zhicheng et al. [16] researched the assessment of TMA impacts in Indonesia's process sector. Plant availability and downtime loss were the important factors utilised to examine TMA's impact. The outcome revealed a link between TMA occurrences and rising availability of 0.315 and a correlation between growing downtime loss of -0.818. The correlation value demonstrates that TMA significantly affects plant availability and downtime loss in real-world process industry practice. Furthermore, Akbar and Ghazali [17] researched the impact of team alignment on the coordination performance of plant TMA in a Malaysian process-based sector. The study employed a survey technique to collect data from cement factories and electric power-producing facilities. The data were gathered using a straightforward random sampling approach.

A satisfactory response rate of 32 percent was obtained from the data gathered from 31 out of 96 firms. The empirical findings demonstrated that team alignment and coordination in plant turnaround maintenance improve performance. Also, Shou et al. [18] in Australia conducted a study on using 4D building information modelling to

enhance TMA in plants. The findings demonstrated that the use of building information modelling was able to ensure that TMA began on time, finished 9.6 hours ahead of schedule and 2.4 days ahead of the original schedule, as well as save a significant amount of maintenance costs in comparison to the actual cost with the initial budget.

Summarily, the extensive literature review on TMA in petrochemical and refinery plants highlights key phases, challenges, and critical considerations in managing large-scale maintenance projects. The TMA process, involving business planning, conceptual development, detailed planning, pre-turnaround work, execution, and post-turnaround stages, underscores the complexity of balancing budget, deadline, and quality requirements. Notable findings from related studies include custom workforce planning tailored for petrochemical MAs, an optimisation model for TMA scheduling in the oil and gas supply chain, an assessment of TMA impacts in Indonesia, an exploration of team alignment's impact on coordination in Malaysian plant TMAs, and successful use of 4D building information modelling to enhance TMA efficiency in Australian plants. These findings collectively contribute insights into workforce optimisation, planning procedures, and the coordination and performance aspects of plant TMA, forming a valuable foundation for the current research on risk management, project management tools, and teamwork in executing TMA activities. The research noted that there are only a few studies on the extent to which project management tools, risk management, and collaboration are used in increasing the efficacy of TMA, despite Africa and other developing countries' position in crude oil production. Hence, utilising the survey technique, this study seeks to fill this gap, using Nigeria as a case study.

3.Methodology

The current study used a survey research methodology. It is described as gathering information by delivering a questionnaire to pertinent individuals [19]–[25]. The employees of the refinery understudy linked directly with maintenance activities are the pertinent parties in this situation. Using the formula provided in Eq. (1). by Taro Yamane [26], the sample size (SS) employed for this study with a total population of 2,312 components was established.

$$SS = \frac{N}{1+Ne^2} \quad \text{Eq. (1).}$$

Here, N is the population's known (limited) size, and e is the sampling error (taken as 5 percent). Applying Eq. (1), the sample size (SS) was obtained as 341 employees. Hence, 341 respondents were included in the sample size and received questionnaires using random sampling. They included 65 respondents from the Maintenance Planning Department, 150 from the Maintenance Department, 10 from the Engineering and Technical Services Department, 65 from the Health Services and Environment Department, 26 as Contractors, and 25 from the Supply Chain Management Department.

Due to the nature of this investigation, a combination of primary and secondary data-gathering methods were used. Primary data collected through physical copies of a specially developed questionnaire were given precedence. The main data sources were gathered by two authors directly from the organisation between December 2020 and January 2021.

The hypotheses (relationship between project management and TMA, risk management and TMA, and teamwork and TMA) were used to create the questionnaire.

H_{o1}: There is no significant relationship between risk management and TMA

H_{o2}: There is no significant connection between TMA and project management systems

H_{o3}: There is no significant connection between TMA and teamwork

The questionnaire had two components: Section A provides demographic data such as qualification and years of experience (2 questions). Section B: Through direct questions, the responder evaluates the relationship between risk management, project management tools, and project teamwork as independent variables on project success as the dependent variable (14 questions). Strongly Agree to Strongly Disagree on a 5-point Likert scale was used to gather the responses. These inquiries came from earlier research by Ghaithan [13] and Zhicheng et al. [16].

The data was analysed using inferential statistics in Microsoft Excel (Version 2019), utilising frequency counts and percentages as the data collection methods. The mean

responses of the respondents were utilised to answer the research questions. However, the Pearson Correlation Coefficient Statistical (PPMC) tool was employed to investigate the study hypotheses utilising the SPSS (Version 26) Software. Based on the significance threshold, the level of each of the independent variable impact or correlation on the dependent variable is measured in correlation index r-value, which is compared with a correlation r critical obtained from a Pearson correlation table using the df (degree of freedom) values in each of the hypotheses, the decision to reject the null hypothesis or accept the alternate hypothesis is based on the 0.05 alpha level of significance.

4.Results And Discussion

Demographic Information of the Respondents

Information about the years of experience and qualifications of the respondents of the organisation that made up the sample size is shown in Table 1. The result shows the distribution of years of experience of the respondents in which the majority of the respondents (90.32%) have between 11 years to 30 years (sum of 46.04% and 44.28% for 11-20 years and 21-30 years, respectively) of experience in the petrochemical and refinery industry. This result denotes adequate knowledge from the sample size that made up this study, thereby rendering their findings from the place of experience and perspectives valid. Furthermore, the majority (43.99%) of the respondents have a BSc. /B.Eng. academic qualifications, followed by 21.41% with an HND degree, 19.65% with a Masters degree, 8.80% with a PGDE degree, and only 6.16% have a Diploma/ND degree. This result shows that all the respondents have adequate exposure and academic background that can render their perspectives on the utilisation of risk management, project management tools and teamwork for the execution of TMA in petrochemical and refinery companies.

Table 1. Demographic information of the respondents

Variable	Frequency	Percentage
Years of Experience		
0-10	16	4.69%
11-20	157	46.04%

21-30	151	44.28%
31-40	17	4.99%
Qualification		
Diploma/ND	21	6.16%
HND	73	21.41%
B.Sc./B.Eng.	150	43.99%
Masters	67	19.65%
PGDE	30	8.80%

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Risk Management

From the result obtained in this study, shown in Table 2, it was observed that the majority of the respondents with a mean value of 4.20 agreed that for project success of the petrochemical and refinery industry understudy, the level of risk management has a significant effect. The respondents specifically believed that the appointment of a risk management team significantly contributes positively to TMA success, and this item had the highest mean of 4.28. Furthermore, the result showed that detailed risk control/reduction plans significantly contribute positively to TMA success, as this had the second-highest mean response of 4.22. Hence, to bring into context the findings of this result, it is important to consider the risk management team and detailed risk control/reduction plans to effectively apply risk management in ensuring project success. This result is supported by the findings of Mahamadi et al. [27].

Table 2. The perspective of the respondents on the application of risk management in TMA

S/N	Items	Response categories					Mean
		SA (5)	A (4)	UD (3)	D (2)	SD (1)	
1	Systematic risk identification will significantly contribute positively to turnaround maintenance success	158	117	50	12	4	4.21
2	Probabilistic/likelihood analysis of risk levels will significantly contribute positively to turnaround maintenance success	136	120	72	4	9	4.09
3	Detailed risk control/reduction plans will significantly contribute positively to turnaround maintenance success	148	135	50	2	6	4.22
4	The appointment of a risk manager will significantly contribute positively to turnaround maintenance success	151	126	56	2	6	4.21
5	Appointment of a risk management team will significantly contribute positively to turnaround maintenance success	159	130	44	4	4	4.28

SA: Strongly Agree, A: Agree, UD: Undecided, D: Disagree, SD: Strongly Disagree

Furthermore, the outcome of the PPMC statistics (Table 3) revealed that there is a significant relationship between risk management and TMA. From the analysis, the calculated p-value of 0.010 is lower than the 0.05 alpha significance level, and the computed R correlation value of 0.617 is higher than the critical r value of 0.113 at df 339. Hence, the null hypothesis of no significant relationship between risk management and TMA is rejected.

Table 3. PPMC statistics on the relationship between risk management, project management tools and teamwork on TMA.

Variables	**N**	**Mean**	**STD**	**df**	**Correlation Index r**	**r critical**	**p**
TMA	341	21.0117	3.50544	339	0.617**	0.113	0.010
Risk Management	341	19.3959	4.31262				
TMA	341	21.3900	3.74131	339	0.742**	0.113	0.002
Project Management Tools	341	19.8592	4.39560				
TMA	341	17.5220	2.66408	339	0.714**	0.113	0.002
Team Work	341	16.5513	3.20126				

**Correlation is significant at the 0.05 level (2-tailed)

Project Management Tools

Additionally, it was noted from the findings of this study, which are presented in Table 4, that the majority of respondents, with a mean value of 4.28, agreed that the successful use of project management tools has a significant impact on the project success of the understudied petrochemical and refinery industry.

Particularly, the usage of the responsibility assignment matrix (RACI), which had the highest mean agreement level of 4.30, greatly adds to the success of TMA. Additionally, the respondents felt strongly that the effectiveness of TMA is highly influenced by the usage of network scheduling techniques (such as CPM, and PERT). The second-highest mean score of 4.28 confirms this. The obtained result is in line with the findings of Dwi et al. [28] and Bagshaw [29].

Table 4. The perspective of the respondents on the application of project management tools on TMA

S/N	Items	Response categories					Mean
		SA (5)	A (4)	UD (3)	D (2)	SD (1)	
1	The use of a work breakdown structure (WBS) significantly contributes positively to turnaround maintenance success	188	89	44	10	10	4.28
2	The use of network scheduling techniques (i.e., CPM, PERT) significantly contributes positively to turnaround maintenance success	169	118	38	12	4	4.28
3	The use of Gant chart significantly contributes positively to turnaround maintenance success	166	117	46	6	6	4.26
4	The use of a responsibility assignment matrix (RACI) significantly contributes positively to turnaround maintenance success	162	133	36	6	4	4.30
5	The use of earned value management (EVM) significantly	177	108	40	4	12	4.27

	contributes positively to turnaround maintenance success						

SA: Strongly Agree, A: Agree, UD: Undecided, D: Disagree, SD: Strongly Disagree

Additionally, the results of the PPMC data (Table 2) showed a substantial correlation between TMA and project management tools. According to the study, the computed p-value of 0.002 is less than the alpha level of 0.05, while the computed R correlation value of 0.742 is more than the crucial r value of 0.113 at df 339. Therefore, the null hypothesis of no significant connection between TMA and project management systems is rejected.

Team Work

The results of this survey, shown in Table 5, also revealed that most respondents, with a mean value of 4.38, agreed that good teamwork substantially impacted the project success of the under-researched petrochemical and refinery business. The success of TMA is particularly impacted by the balance of member contributions, as seen by the fact that this item had the highest mean response at 4.45. The second-highest mean response, 4.37, indicates that the respondents strongly agreed that the team members' mutual support is a key factor in the success of TMA. The outcome is consistent with those seen in the study of Rogers [30] and Gunduz and Yahya [31].

Table 5. The perspective of the respondents on the application of teamwork in TMA

S/N	**Items**	**Response categories**					**Mean**
		SA (5)	**A (4)**	**UD (3)**	**D (2)**	**SD (1)**	
1	Effective communication (meeting regularly and other mediums of information exchange) significantly contributes to turnaround maintenance success	183	116	28	8	6	4.35

2	Effective coordination of subtasks, schedules and deliverables significantly contributes to turnaround maintenance success	189	94	50	4	4	4.35
3	Balance of member contribution significantly contributes to turnaround maintenance success	193	118	24	2	4	4.45
4	Mutual support from your team members significantly contributes to turnaround maintenance success	196	91	44	4	6	4.37

SA: Strongly Agree, A: Agree, UD: Undecided, D: Disagree, SD: Strongly Disagree

Additionally, the results of the PPMC data (Table 2) showed that there is a substantial correlation between TMA and teamwork. According to the study, the computed p-value of 0.002 is less than the alpha level of 0.05, while the computed R correlation value of 0.714 is more than the crucial r value of 0.113 at df 339. Therefore, the null hypothesis of no significant connection between TMA and teamwork is rejected.

As identified from the survey findings, the key elements of risk management, project management tools, and teamwork play integral roles in the success of TMA activities in the petrochemical and refinery industry. The relationships between key elements and subfactors in maintenance activities are shown in Figure 1. In terms of risk management, systematic risk identification involves conducting thorough surveys to identify potential risks associated with TMA.

Probabilistic analysis, such as quantification, is crucial for assessing the likelihood of these risks, allowing for informed decision-making. Detailed risk control plans, or mitigation strategies, are essential for minimising the impact of identified risks. The appointment of a dedicated risk manager and forming a risk management team demonstrate leadership and collaboration, fostering a proactive approach to risk mitigation.

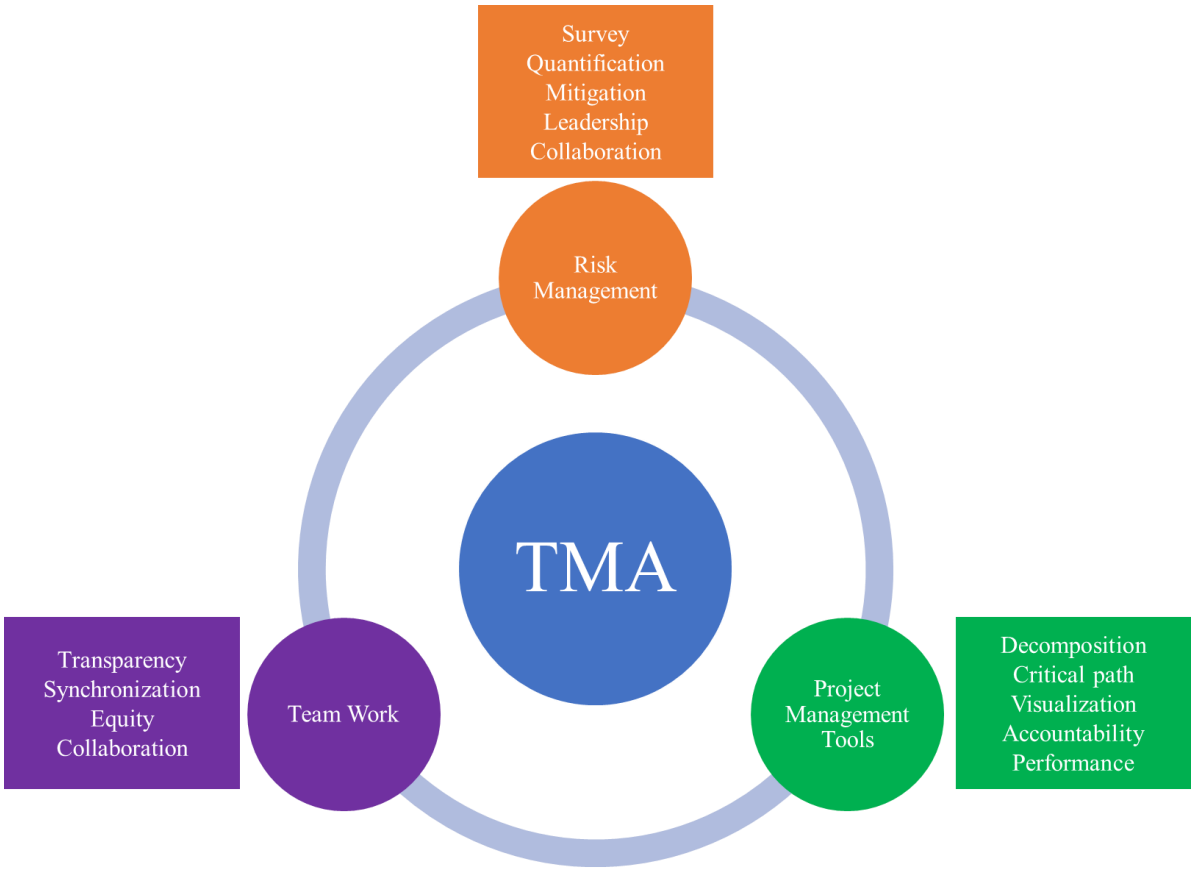

Figure 1. Relationships between key elements and subfactors in maintenance activities

Nevertheless, using risk management tools for TMA is not a novel concept in the chemical industry as stated by Muller [32]; however, restrictive approaches often hinder its effectiveness. Turnarounds and substantial capital projects, characterised by numerous variables and constant changes, demand a shift from viewing risk as a static obstacle to adopting a dynamic approach. In this context, continuous application of risk identification and mitigation tools throughout the planning and scheduling processes is imperative. Another challenge in integrating risk management into TMA in petrochemical industries lies in the common difficulty people face in comprehending probability concepts, leading to an inclination to overemphasise the likelihood of extraordinary events over more commonplace occurrences, as also confirmed in the study of AlHamouri et al. [6]. This bias can provide a false sense of security during execution, exposing projects and teams to significant dangers. A genuine understanding of risks' probability,

severity, and criticality demands experience and sound judgment, which can be obtained through leadership and collaboration, as identified in this study.

In the realm of project management tools, using WBS facilitates the decomposition of complex TMA projects into manageable tasks, ensuring a systematic approach to execution. Network scheduling techniques, including CPM and PERT, assist in identifying critical paths and scheduling, with visualisation through Gantt charts providing a comprehensive overview. A RACI ensures accountability, while EVM offers insights into project performance. Aside from these project management tools used in the understudy refinery for TMA, recent studies have highlighted the latest tools, such as Primavera, STO Planner, and iPlanSTO, as emerging technologies used in advanced refineries [33], [34]. Furthermore, drones now play a crucial role in inspecting hard-to-reach refinery equipment, particularly in remote or challenging environments [35]. Digital plant modelling has advanced, allowing the creation of digital replicas to monitor production and equipment under varying conditions in these refineries [34]. Leveraging data analytics and artificial intelligence on maintenance data provides valuable insights from historical information. Additionally, Industrial Internet of Things (IIoT) technologies enable real-time data collection and sharing, significantly improving the assessment of critical equipment's scope of work [36].

Teamwork is a cornerstone in TMA, and effective communication, exemplified by transparency, is crucial for conveying project goals, progress, and potential challenges. Coordination of subtasks, schedules, and deliverables through synchronisation enhances overall project efficiency. A balance of member contributions, emphasising equity, ensures that each team member plays a meaningful role, contributing to the success of the TMA. Mutual support among team members fosters collaboration, creating a positive and synergistic working environment essential for overcoming the complexities of TMA in the petrochemical and refinery industry. To align with these findings, previous studies showed the significance of aligning teams and groups involved in plant turnaround maintenance and established a strong correlation between teamwork and performance in plant turnaround maintenance [17], [37].

5.Conclusion

This study is based on project management tools, risk management techniques, and teamwork in a typical Nigerian petrochemical and refinery business, one of the world's major emerging oil producers. A structured questionnaire based on three sub-hypotheses on the importance of the management tools under research on TMA in the petrochemical and refinery industry was devised to fulfil the study's general purpose. The employees of the respondents that participated in the survey were 341 carefully chosen employees from several departments, including supply chain management, engineering and technical services, health services, and maintenance. The sub-hypotheses were examined using inferential statistics and Pearson correlation analysis. The study's findings demonstrated a substantial association between the management tools and TMA, with R-values for these relationships being 0.617, 0.742, and 0.714 for those with risk management, project management tools, and teamwork, respectively.

Moreover, the investigation results indicated a widespread consensus among the participants, expressing strong concurrence that the effective execution of TMA in the petrochemical and refinery sector relies significantly on sound risk management methodologies (p-value = 0.01). Similarly, project management tools were crucial for successful TMA implementation (p-value = 0.002). Additionally, the study highlighted the vital role of well-integrated teamwork in the TMA process, with the significance reflected in the p-value of 0.002. Therefore, these efficient management methods are recommended to be implemented with other effective tools from previous sectors to guarantee efficient TMA in the petrochemical and refinery industries.

Acknowledgement

The authors thank the staff of Kaduna Refining and Petrochemical Company and the Department of Mechanical Engineering, Ahmadu Bello University, Zaria, Nigeria.

Competing Interests

The authors declare that they have no competing interests.

Availability of Supporting Data

The data sets supporting the results of this article are available upon reasonable request.

Ethical Approval and Consent to Participate

Before conducting interviews, a verbal agreement was sought from each participant, and all respondents who took part in the field study were fully informed of the project's goals and their opportunity to opt out.

Funding

The study did not receive any external funding

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