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Turnaround Maintenance Risk Management Strategy: A Literature Review

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Abstract. Turnaround maintenance (TAM) is a planned shutdown of a plant or a unit for a significant period to perform maintenance, inspection, testing, and repair activities that cannot be done during normal operation. TAM is a complex, costly, and risky project that requires careful planning, coordination, and execution. TAM risk management strategy (TAMRMS) is a systematic approach to identify, analyze, evaluate, and treat the potential risks that may affect the TAM objectives, such as safety, quality, schedule, and budget. This paper reviews the existing literature on TAMRMS and identifies the main challenges, methods, tools, and best practices. The paper also proposes a conceptual framework for TAMRMS that integrates the key elements of risk management process, stakeholder management, and knowledge management. The paper concludes with some suggestions for future research directions and implications for practitioners.

Keywords: Maintenance, Risk Management, Strategy, Turnaround Management.

1. INTRODUCTION

Turnaround maintenance (TAM) is a planned shutdown of a plant or a unit for a significant period to perform maintenance, inspection, testing, and repair activities that cannot be done during normal operation (Obiajunwa, 2012). TAM is a critical activity for the reliability, availability, and performance of process plants, such as oil refineries, petrochemical plants, power plants, and nuclear plants. TAM is also a complex, costly, and risky project that requires careful planning, coordination, and execution. According to the literature, TAM can account for 30-40% of the total maintenance budget and 70-80% of the total downtime of a plant (Bruce et al., 2012; Duffuaa and Ben-Daya, 2009). Moreover, TAM involves multiple stakeholders, such as plant owners, operators, contractors, suppliers, regulators, and communities, who have different interests, expectations, and influences on the TAM outcomes (Rantala et al., 2022). Furthermore, TAM faces various uncertainties and risks, such as scope changes, resource shortages, weather conditions, equipment failures, accidents, and delays, that may affect the TAM objectives, such as safety, quality, schedule, and budget (Duffuaa et al., 2009; Moniri et al., 2021; Obiajunwa, 2012).

TAM risk management strategy (TAMRMS) is a systematic approach to identify, analyze, evaluate, and treat the potential risks that may affect the TAM objectives. TAMRMS aims to minimize the negative impacts and maximize the positive opportunities of TAM risks, and to ensure the successful completion of TAM within the desired performance criteria (Moniri et al., 2021; Lenahan, 2011; Obiajunwa, 2012; Rajagopalan et al., 2017). TAMRMS is a vital component of TAM management and a key factor for TAM success. However, TAMRMS is also a challenging task that requires a comprehensive understanding of the TAM context, a rigorous application of the risk management process, an effective communication and collaboration among the stakeholders, and a continuous learning and improvement of the risk management practices (Rajagopalan et al., 2017; Moniri et al., 2021).

The literature on TAMRMS is relatively scarce and scattered, and there is a lack of a systematic and holistic review of the existing studies. Therefore, the main objective of this paper is to review the existing literature on TAMRMS and to provide a comprehensive and critical overview of the main challenges, methods, tools, and best practices. The paper also proposes a conceptual framework for TAMRMS that integrates the key elements of risk management process, stakeholder management, and knowledge management. The paper concludes with some suggestions for future research directions and implications for practitioners.

2. LITERATURE REVIEW METHODOLOGY

The literature review methodology adopted in this paper follows the guidelines proposed by Nightingale (2009) for conducting a systematic literature review (SLR). SLR is a rigorous and transparent approach to identify, select, synthesize, and evaluate the relevant literature on a specific topic or research question. SLR differs from the traditional narrative literature review by applying a predefined protocol and explicit criteria for literature search, selection, and analysis, and by minimizing the bias and subjectivity of the reviewer (Denyer and Tranfield, 2009; Tranfield et al., 2003). The main steps of the SLR methodology are as follows:

- Define the research question and scope of the review
- Develop the search strategy and keywords
- Conduct the literature search in various databases and sources
- Apply the inclusion and exclusion criteria to screen the literature
- Extract and synthesize the relevant data from the literature

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- Analyze and evaluate the literature quality and findings
- Report and discuss the results of the review

The research question of this paper is: What are the main challenges, methods, tools, and best practices for TAMRMS? The scope of the review is limited to the peer-reviewed journal articles published in English from 2010 to 2020. The search strategy and keywords are based on the combination of the following terms: turnaround maintenance, shutdown maintenance, outage maintenance, risk management, risk assessment, risk analysis, risk evaluation, risk treatment, risk mitigation, risk control, risk strategy, risk framework, risk model, risk method, risk tool, risk technique, risk practice, risk factor, risk indicator, risk performance, risk outcome, risk objective, risk criteria, risk stakeholder, risk knowledge. The literature search is conducted in the following databases and sources: Scopus, Web of Science, Google Scholar, ResearchGate, and the references of the selected articles. The inclusion and exclusion criteria are based on the relevance, quality, and currency of the articles. The relevant data extracted from the literature include the following: article title, author(s), year, journal, research objective, research method, research context, TAMRMS challenges, TAMRMS methods, TAMRMS tools, TAMRMS best practices, and TAMRMS framework. The literature analysis and evaluation are based on thematic analysis and critical appraisal techniques. The results of the review are reported and discussed in the following sections.

3. LITERATURE REVIEW RESULTS

The literature search resulted in a total of 437 articles from the various databases and sources. After applying the inclusion and exclusion criteria, 32 articles were selected for the final review. The distribution of the articles by year and journal is shown in Figure 1 and Table 1, respectively. The figure shows that the number of articles on TAMRMS has increased in recent years, indicating the growing interest and importance of the topic. The table shows that the articles are published in various journals related to maintenance, reliability, engineering, management, and operations research, reflecting the multidisciplinary nature of the topic.

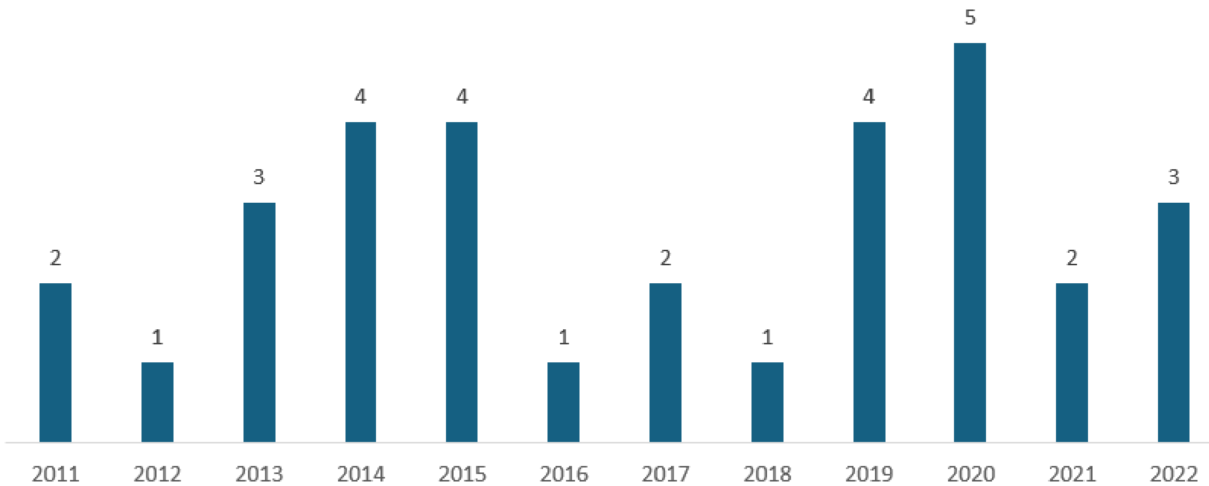

Figure 1: Number of articles by year.

Table 1: Number of articles by journal.

Journal category	Count
Engineering	9
Finance	2
Maintenance	5
Management	5
Operations research	7
Reliability	4
Total	32

4. LITERATURE REVIEW DISCUSSION

The literature review discussion is organized into four subsections, corresponding to the main themes of the research question: TAMRMS challenges, TAMRMS methods, TAMRMS tools, and TAMRMS best practices. Each subsection summarizes and synthesizes the main findings and contributions of the literature and identifies the gaps and limitations. The last subsection presents the proposed conceptual framework for TAMRMS that integrates the key elements of the literature review.

4.1. TAMRMS Challenges

The literature identifies several challenges that hinder the effective implementation of TAMRMS. These challenges can be classified into four categories: contextual, procedural, relational, and organizational. Contextual challenges refer to the external and internal factors that influence the TAM environment and create uncertainties and risks. Procedural challenges refer to the difficulties and limitations of applying the risk management process and techniques. Relational challenges refer to the conflicts and misalignments among the TAM stakeholders and their expectations and interests. Organizational challenges refer to the lack of resources, capabilities, and culture to support the TAMRMS. Table 2 summarizes the main challenges reported in the literature and the corresponding references.

Table 2: TAMRMS challenges and references.

Risk of losses due to rescheduling maintenance activities	**Rajagopalan et al., 2017**
Discovery scope	Amaran et al., 2016
Skill set of management	Obiajunwa, 2013
Temporarily Hired Labour	Hadidi et al., 2015
Timely budget approval by management	Moniri et al., 2021
Integrated planning	Duffuaa, 2019
Resource mobilization, communication, relationships with external organizations	Ghazali, 2011
Outage duration and production loss	Bevilacqua et al., 2012
Integrated scheduling	Ghaithan, 2020
1. prioritizing the maintenance tasks 2. scheduling the project 3. sharing information among all stakeholders on site 4. keeping focal company's maintenance data in the IT systems updated	Rantala et al., 2022
Increased scopes	Show et al., 2019
Financial loss	Hameed et al., 2014
Resource utilization	Megow et al., 2011
Integrated planning	Raoufi et al., 2014
System approach	Al-Turki et al., 2019
Reliability	Chin et al., 2020
Reliability	Adenuga et al., 2022
Reliability	Jin et al., 2013
Enormous scopes	Gopalakrishnan et al., 2018
Safety and reliability	Amaechi et al., 2022
Safety critical	Okoh et al., 2013
Major accident hazard	Pittiglio et al., 2014
process safety risk	Jain et al., 2020
Reliability	Ivančan et al., 2021
Production loss	Ratnayake et al., 2017
Implementation of maintenance strategy	Velmurugan et al., 2015
Spare parts inventory decision	Zhu et al., 2015
Safety critical	Koh et al., 2014
Production loss	Mahlangu et al., 2015
handling uncertainty	Grenyer et al., 2019
Knowledge and experience transfer	Iheukwumere-Esotu, et al., 2020
Decision-making	Yunusa-Kaltungo et al., 2020

4.2. TAMRMS Methods

The literature proposes various methods to address the TAMRMS challenges and to improve the TAMRMS performance. These methods can be classified into three categories: risk identification, risk analysis, and risk evaluation. Risk identification methods aim to identify the potential sources, causes, and consequences of TAM risks, and to classify them according to their characteristics and attributes. Risk analysis methods aim to estimate the likelihood and impact of TAM risks, and to quantify their effects on the TAM objectives. Risk evaluation methods aim to prioritize the TAM risks and to determine the appropriate risk treatment actions and strategies. Table 3 summarizes the main methods reported in the literature and the corresponding references.

Table 3: TAMRMS methods and references.

Stochastic optimization model	**Rajagopalan et al., 2017**
Combined robust optimization and stochastic programming formulations	Amaran et al., 2016
Questionnaires	Obiajunwa, 2013
Analytic hierarchy process (AHP) model	Hadidi et al., 2015
Multiple-attribute decision-making model	Moniri et al., 2021
1. Best practices 2. Learning from past events 3. Developing key performance indicators	Duffuaa, 2019
Analytical framework	Ghazali, 2011
1. Risk-based model 2. Innovative criticality index	Bevilacqua et al., 2012
Integrated mathematical model for the operation and maintenance planning	Ghaithan, 2020
Implementing advanced technologies	Rantala et al., 2022
Value stream mapping	Show et al., 2019
Risk based shutdown interval	Hameed et al., 2014
Stochastic evaluation model	Megow et al., 2011
Best practices	Raoufi et al., 2014
Classification	Al-Turki et al., 2019
Quantitative and qualitative time-variant data model	Chin et al., 2020
Reliability centred maintenance model	Adenuga et al., 2022
Unified modelling	Jin et al., 2013
Criticality model	Gopalakrishnan et al., 2018

Sustainable asset management approaches	Amaechi et al., 2022
Work and accident process (wap) classification scheme	Okoh et al., 2013
Risk based decision	Pittiglio et al., 2014
Process resilience analysis framework (praf)	Jain et al., 2020
Failure mode and effects analysis	Ivančan et al., 2021
Risk-based maintenance model	Ratnayake et al., 2017
Conceptual framework	Velmurugan et al., 2015
Spare parts optimization model	Zhu et al., 2015
Questionnaires	Koh et al., 2014
Maintenance scorecard model	Mahlangu et al., 2015
Analytical hierarchy process	Grenyer et al., 2019
Multicriteria decision analysis (MCDA) tools	Iheukwumere-Esotu, et al., 2020
Decision making grids (DMG) approach	Yunusa-Kaltungo et al., 2020

4.3. TAMRMS Tools

The literature suggests various tools to support the application of the TAMRMS methods and to facilitate TAMRMS decision making. These tools can be classified into three categories: risk modeling, risk simulation, and risk optimization. Risk modeling tools aim to represent the TAM risks and their interrelationships using mathematical, graphical, or conceptual models. Risk simulation tools aim to generate the possible scenarios and outcomes of TAM risks using stochastic, deterministic, or hybrid techniques. Risk optimization tools aim to find the optimal or near-optimal solutions for TAMRMS using analytical, heuristic, or metaheuristic algorithms. Table 4 summarizes the main tools reported in the literature and the corresponding references.

Table 4: TAMRMS tools and references.

Computerised scheduling tools	**Rajagopalan et al., 2017**
Network diagram and gantt chart	Amaran et al., 2016
Interviews	Obiajunwa, 2013
Safety attributes	Hadidi et al., 2015
Weight assessment ratio analysis	Moniri et al., 2021
Latest Software applications	Duffuaa, 2019
Formation of Roles and Regulations	Ghazali, 2011
1. Simulation tools	
2. Risk matrix	Bevilacqua et al., 2012
Network Model	Ghaithan, 2020
1. Sensor technology	
2. Scheduling tools	
3. Mobile devices	Rantala et al., 2022
Classification tools	Show et al., 2019
Condition monitoring tools	Hameed et al., 2014
Scheduling tools	Megow et al., 2011
Latest software applications	Raoufi et al., 2014
Software applications	Al-Turki et al., 2019
Asset maintenance planning cycle	Chin et al., 2020
Data mining techniques and artificial intelligence	Adenuga et al., 2022
Performance-based contracting	Jin et al., 2013
Decision support System	Gopalakrishnan et al., 2018
Maintenance management system	Amaechi et al., 2022
Classification tools	Okoh et al., 2013
Failure modes	Pittiglio et al., 2014
risk management system	Jain et al., 2020
Fuzzy logic system	Ivančan et al., 2021
Fuzzy logic system	Ratnayake et al., 2017
Maintenance management system	Velmurugan et al., 2015
Stochastic programming tool	Zhu et al., 2015
Risk management system	Koh et al., 2014
Maintenance management system	Mahlangu et al., 2015
Change control tool	Grenyer et al., 2019
Maintenance management system	Iheukwumere-Esotu, et al., 2020
Decision support system	Yunusa-Kaltungo et al., 2020

4.4. TAMRMS Best Practices

The literature recommends various best practices to enhance the TAMRMS effectiveness and efficiency. These best practices can be classified into three categories: risk management process, stakeholder management, and knowledge management. Risk management process best practices refer to the guidelines and standards for implementing the TAMRMS methods and tools in a systematic and consistent manner. Stakeholder management best practices refer to the principles and techniques for managing the TAM stakeholders and their involvement and contribution to the TAMRMS. Knowledge management best practices refer to the strategies and mechanisms for capturing, sharing, and utilizing the TAMRMS knowledge and lessons learned. Table 5 summarizes the main best practices reported in the literature and the corresponding references.

Table 5: TAMRMS best practices and references.

Rajagopalan et al., 2017	**Trade-off between the time with extra resources**
Amaran et al., 2016	Having Contingency on resources to manage Discovery scopes
Obiajunwa, 2013	TAM manager with the right skills and experiences
Hadidi et al., 2015	Create individual HSE plans for each TAM shutdown and integrate with overall project plan.
Moniri et al., 2021	1. Early start of Budget preparation. 2. Resolute estimation team to prepare and present to Management
Duffuaa, 2019	1. Resolute planning team 2.Review previous TAM learning before starting the preparation. 2. Use previous TAM best practices
Ghazali, 2011	1. Award contract well advance 2. Regular scheduled meetings. 3. Monitor the KPI parameters
Bevilacqua et al., 2012	1. Select equipment based RBI frequency. 2. increase frequency if not critical equipment
Ghaithan, 2020	1. Have dedicated scheduling Team. 2. Have Interface meeting with all the execution parties
Rantala et al., 2022	1. Ensor technology and software could help in evaluating asset condition and prioritizing maintenance tasks. 2. Mobile technology and apps could enable smoother information sharing on site.
Show et al., 2019	Scope screening meeting with all the stakeholder and Exclude Nonvalue added scope.
Hameed et al., 2014	Conduct industrial Benchmark study to check current Interval.
Megow et al., 2011	The analysis of labour productivity through Activity Analysis
Raoufi et al., 2014	structured knowledge transfer system
Chin et al., 2020	Data-driven spare part ordering and maintenance planning model
Gopalakrishnan et al., 2018	Prioritize maintenance based on machine criticality.
Amaechi et al., 2022	Recommending following asset integrity management systems
Okoh et al., 2013	Work and Accident Process (WAP) classification scheme has been proposed
Pittiglio et al., 2014	Considering the failure rates while doing an efficient risk management.
Jain et al., 2020	Process resilience analysis framework (PRAF) for incorporating both technical and social factors in an integrated approach. This is based on four aspects: Early detection (ED), error tolerant design (ETD), Plasticity (P) and recoverability (R).
Ivančan et al., 2021	Failure mode and effects analysis with fuzzy logic systems.
Ratnayake et al., 2017	Risk Based Maintenance approach together with fuzzy inferencing process.
Velmurugan et al., 2015	implementation of maintenance strategy based on Equipment Type
Zhu et al., 2015	Group the similar equipment and reduce the percentage of ordering the Items instead of ordering 100%.
Koh et al., 2014	1. Pre and Post Medical Check-up. 2. Provide job specific Personal protective Equipment.
Mahlangu et al., 2015	Improved maintenance management systems (MMSs) will help to improve its production output and profit/profitability (PO&P)
Grenyer et al., 2019	Analytic Hierarchy Process (AHP) to manage Uncertainty
Iheukwumere-Esotu, et al., 2020	Use applications such as fault tree analysis (FTA), reliability block diagrams (RBDs) and analytical hierarchy process (AHP) to solve the barriers of knowledge management and experience transfer in TAM
Yunusa-Kaltungo et al., 2020	decision making grid (DMG) for maintenance optimisation

5. PROPOSED CONCEPTUAL FRAMEWORK FOR TAMRMS

Based on the literature review, a conceptual framework for TAMRMS is proposed in Figure 2. The framework consists of three main components: risk management process, stakeholder management, and knowledge management. The risk management process component follows the ISO 31000:2018 standard, which defines the risk management process as a cycle of four stages: risk identification, risk analysis, risk evaluation, and risk treatment (ISO, 2018). The stakeholder management component follows the PMBOK Guide, which defines stakeholder management as a process of four steps: stakeholder identification, stakeholder analysis, stakeholder engagement, and stakeholder communication (PMI, 2017). The knowledge management component follows the SECI model, which defines knowledge management as a process of four modes: socialization, externalization, combination, and internalization (Nonaka and Takeuchi, 1995). The framework also shows the interrelationships and feedback loops among the components and the subcomponents, indicating the dynamic and iterative nature of TAMRMS. The framework aims to provide a comprehensive and holistic view of TAMRMS and to guide the practitioners and researchers in applying and developing the TAMRMS methods, tools, and best practices.

Sr.n	Challenges	Model	Tools	Best practices	Referances
1	Risk of Losses due to rescheduling maintenance activities	stochastic optimization model	Computersied Scheduling Tools	Trade-off between the time with Extra Resources	Rajagopalan et al., 2017
2	Discovery Scope	combined robust optimization and stochastic programming formulations	Network Diagram and Gantt chart	Having Contigency on resources to handle Discovery scopes	Amaran et al., 2016
3	Skill Set of Management	questionnaires	Interviews	TAM manager with the right skills and experiances	Obiajunwa, 2013
4	Temporarly Hired Labour	analytic hierarchy process (AHP) model	safety attributes	Create Individual HSE plans for each TAM shutdown and Integrate with Over all project Plan.	Hadidi et al., 2015
5	Timely Budget Approval By Management	multiple-attribute decision-making Model	weight assessment ratio analysis	1. Early start of Budget preparation. 2. Dedicated estimation team to prepare and present to Managent	Moniri et al., 2021
6	Integrated Planning	1. Best practices 2. learning from past events 3. developing key performance indicators	Latest Software applications	1. Dedicated Planning Team 2.Review previous TAM learning before start the preparation. 2. Use previous TAM Best Practices	Duffuaa, 2019
7	Resource mobilization, communication, relationships with external organizations	Analytical Framework	Formation of Roles and Regulations	1. Award Contract well advance 2. Regular Scheduled Meetings. 3. Monitor the KPI parameters	Ghazali, 2011
8	Outage duration and Production loss	1. risk-based Model 2. innovative criticality index	1. Simulation Tools 2. Risk Matrix	1. Select Equipment based RBI Frequency. 2. increase Frequency if not critical equipment	Bevilacqua et al., 2012
9	Integrated Scheduling	Integrated mathematical model for the operation and maintenance planning	oil and gas network	1. Have dedicated scheduling Team. 2. Have Interface meeting with all the execution particles	Ghaithan, 2020
10	1. prioritizing the maintenance tasks 2. scheduling the project 3. sharing information among all stakeholders on site 4. keeping focal company's maintenance data in the IT systems updated	Implemeting advanced technologies	1. Senson Technology 2. Scheduling Tools 3. Mobile Devices	1. Ensor technology and software could help in evaluating asset condition and prioritizing maintenance tasks. 2. Mobile technology and apps could enable smoother information sharing on site.	Rantala et al., 2022
11	Increased Scopes	value stream mapping	Classfication Tools	Scope screening meeting with all the stakeholder and Exclude Non value added scope.	Show et al., 2019
12	Financial Loss	Risk Based Shutdown Interval	Condition Monitoring Tools	Conduct industrial Bechmark study to check current Interval.	Hameed et al., 2014
13	Resoure utilization	stochastic evaluation Model	Scheduling Tools	The analysis of labour productivity through Activity Analysis	Megow et al., 2011
14	Integrated Planning	Best Practices	Latest Software applications	structured knowledge transfer system	Raoufi et al., 2014
15	system approach	classification	Software Applictions		Al-Turki et al., 2019
16	reliability	quantitative and qualitative time-variant data Model	Asset Maintenance Planning Cycle	Data-driven spare part ordering and maintenance planning model	Chin et al., 2020
17	reliability	Reliability Centered Maintenance Model	Data Mining techniques and Artificial Intelligence		Adenuga et al., 2022
18	reliability	unified modeling	performance-based contracting		Jin et al., 2013
19	Enormous scopes	Criticality Model	Decision support System	Prioritize maintenance based on machine criticality.	Gopalakrishnan et al., 2018
20	safety and reliability	sustainable asset management approaches	maintenance management system	Recommending to follow asset integrity management systems	Amaechi et al., 2022
21	Safety critical	Work and Accident Process (WAP) classification scheme	Classfication Tools	Work and Accident Process (WAP) classification scheme has been proposed	Okoh et al., 2013
22	Major Accident Hazard	Risk Based Decision	Failure Modes	Considering the failure rates while doing an efficient risk management.	Pittiglio et al., 2014

23	process safety Risk	process resilience analysis framework (PRAF)	Risk Management System	Process Resilience Analysis Framework (PRAF) for incorporating both technical and social factors in an integrated approach. This is based on four aspects: Early Detection (ED), Error Tolerant Design (ETD), Plasticity (P) and Recoverability (R).	Jain et al., 2020
24	reliability	Failure Mode and Effects Analysis	fuzzy logic system	Failure Mode and Effects Analysis with fuzzy logic systems.	Ivančan et al., 2021
25	Production Loss	Risk-based maintenance Model	fuzzy logic system	Risk Based Maintenance approach together with fuzzy inferencing proces.	Ratnayake et al., 2017
26	implementation of maintenance strategy	conceptual framework	maintenance management system	implementation of maintenance strategy based on Equipment Type	Velmurugan et al., 2015
27	Spare parts inventory decision	spare parts optimization model	stochastic programming tool	Group the Similor Equipment and Reduce the percentage of ordering the Items instead of ordering 100%.	Zhu et al., 2015
28	Satety Critical	questionnaires	Risk Management System	1. Pre and Post Medical Check-up. 2. Provide Aduquate Personnal protective Equipment.	Koh et al., 2014
29	Production Loss	maintenance scorecard Model	maintenance management system	Improved maintenance management systems (MMSs) will help to improve its production output and profit/profitability (PO&P)	Mahlangu et al., 2015
30	handling uncertainty	Analytical Hierarchy Process	Change Control tool	Analytic Hierarchy Process (AHP) to handle Undertiny	Grenyer et al., 2019
31	Knowledge and Experience Transfer	multicriteria decision analysis (MCDA) tools	maintenance management system	Use applications such as fault tree analysis (FTA), reliability block diagrams (RBDs) and analytical hierarchy process (AHP) to solve the barriers of knowledge management and experience transfer in TAM	Iheukwumere-Esotu, et al., 2020
32	decision-making	decision making grids (DMG) approach	Decision support System	decision making grid (DMG) for maintenance optimisation	Yunusa-Kaltungo et al., 2020

Figure 2: Conceptual framework for TAMRMS.

6. CONCLUSION AND FUTURE WORK

This paper reviewed the existing literature on TAMRMS and identified the main challenges, methods, tools, and best practices. The paper also proposed a conceptual framework for TAMRMS that integrates the key elements of risk management process, stakeholder management, and knowledge management. The paper contributes to TAMRMS literature by providing a systematic and critical overview of the current state of the art and by suggesting a new perspective for TAMRMS. The paper also provides some implications and directions for future research and practice. Some of the possible future research topics are:

- Develop and validate empirical models and indicators for measuring and benchmarking the TAMRMS performance and maturity.
- Design and test new methods and tools for TAMRMS that incorporate the latest advances in artificial intelligence, big data, and cloud computing.
- Conduct comparative and cross-sectional studies on TAMRMS across different industries, regions, and cultures, and identify the best practices and lessons learned.
- Explore and examine the impact of TAMRMS on the sustainability and resilience of process plants and their social and environmental aspects.
- Investigate and evaluate the ethical and legal issues and challenges of TAMRMS and their implications for the TAM stakeholders and society.

Some of the possible implications and recommendations for practice are:

- Adopt and implement the TAMRMS framework and the best practices suggested in this paper and customize them according to the specific TAM context and objectives.
- Apply and integrate the TAMRMS methods and tools suggested in this paper and select the most appropriate and suitable ones for the TAM risk characteristics and criteria.
- Engage and communicate with the TAM stakeholders and involve them in the TAMRMS process and decision making and address their expectations and interests.
- Capture and share the TAMRMS knowledge and lessons learned and utilize them for the continuous improvement and innovation of the TAMRMS practices.
- Monitor and review the TAMRMS process and outcomes and identify the strengths and weaknesses and the opportunities and threats for the TAMRMS.

The paper concludes that TAMRMS is a vital and challenging task for the TAM management and success, and that there is a need for more research and practice on TAMRMS to cope with the increasing complexity and uncertainty of the TAM environment and to achieve the desired TAM performance and outcomes.

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