

Research Proposal Title:

**Exploring the Moderating Role of Artificial
Intelligence on the Impact of Quality Management on
Construction Project Outcomes
(A Case Study of Jeddah Stormwater Program)**

For Ph.D. Application

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Introduction

The Saudi Vision 2030 outlines a bold roadmap for national transformation, with infrastructure development playing a pivotal role in improving the quality of life for citizens, fostering vibrant cities, and promoting environmental responsibility. The construction industry is instrumental in realizing these infrastructure goals (Vision2030). Effective quality management is essential for the success of ambitious projects, particularly in construction. Conventional quality management methods, such as inspections, testing, and audits, are often time-consuming, labor-intensive, and susceptible to bias and human error. Organizational culture is also essential in implementing quality management practices (Aichouni *et al.*, 2014). Keeping up with the expanding complexity and size of construction projects can challenge traditional quality management practices. Additionally, the construction industry is encountering various obstacles like tight schedules, budget limitations, and a scarcity of skilled labor. These difficulties underscore the demand for inventive strategies in quality management within construction projects; one promising approach involves incorporating artificial intelligence technology (Seyman-Güray, 2023).

Artificial intelligence (AI) presents the opportunity for a paradigm shift in construction quality management (CQM) by leveraging advanced algorithms and data analysis capabilities, which can improve the efficiency and accuracy of overall traditional quality management practices while also addressing some of the critical challenges faced in the industry. Datta et al., 2024 and Makaula et al., 2021 investigated how harnessing the power of AI by construction companies can potentially automate routine quality control processes, detect defects or deviations more effectively, and optimize resource allocation for improved project outcomes. However, despite the potential benefits of AI in CQM, there is still a gap in understanding the moderating role of AI on the impact of quality management on construction project outcomes (Makaula *et al.*, 2021).

This research will explore the potential of AI technologies, such as machine learning, computer vision, and natural language processing, to enhance existing CQM practices. Recognizing the limited research examining this potential within the Saudi Arabian context and the scarcity of case studies on AI applications in the construction industry, this study will offer valuable insights. Using the Jeddah Stormwater Program as a case study will explore the interplay between AI and established CQM processes in a real-world setting. This aims to reveal the limitations of current practices and the opportunities presented by AI for optimization. It will help in future projects to ensure that AI is effectively integrated and utilized for optimal project results and provide recommendations for researchers, policymakers, and industry professionals in adopting AI for quality management in construction projects.

Keywords

AI in Quality Management, Construction Project Outcomes, Saudi Vision 2030, Infrastructure Projects, Jeddah Stormwater Management

Problem statement

Saudi Vision 2030 sets ambitious infrastructure goals that demand robust quality management in construction, highlighting the potential of Artificial Intelligence (AI) to transform quality practices. Despite this potential, the adoption of AI within the Saudi Arabian construction industry remains limited. Effective quality management is crucial for complex construction projects, yet the impact of CQM can be influenced significantly by technological factors, particularly AI (Neyestani, 2016). Research is crucial to understanding AI's moderating role and its capacity to enhance Construction Quality Management (CQM). This includes exploring how AI-powered data analysis can preemptively identify quality issues, reduce reworks, predict project risks, and optimize resource allocation.

However, limited research exists on how the integration of AI with quality management practices impacts construction project outcomes, particularly within the Saudi Arabian context (Datta et al., 2024). Existing global studies often focus on the general advantages of AI in construction but not the specific challenges and established practices of the Saudi Arabian construction sector. This lack of focused research hinders our understanding of effectively integrating these technologies

with existing quality practices to optimize project outcomes. This research aims to fill this gap by focusing on the integration of AI into CQM practices, particularly in the context of stormwater network projects, examining several key aspects and identifying the most impactful ways to tailor AI solutions to the unique context of Saudi Arabia's construction industry. Successful Integration of AI will benefit JSWP in overcoming some of the associated quality issues and concerns in four major areas of the projects, those areas are:

1. **Quality Planning:** Exploring how AI-enhanced planning can mitigate cost overruns and delays, thereby improving economic and temporal efficiency in stormwater network projects.
2. **Quality Assurance and Standards Compliance:** Assessing AI's role in enhancing adherence to project, quality standards, and related project requirements, which are crucial for the integrity of stormwater infrastructure.
3. **Quality Control:** Analyzing how AI-driven tools detect/predict and correct defects early in construction.
4. **Quality Improvement and corrective/Preventive actions:** Investigating how AI contributes to the sustainability and resilience of stormwater networks, particularly through failure detection as well as recommending preventive measures based on pattern recognition from historical data.

Against this backdrop of exploring AI's potential to transform CQM practices, the research is structured around three critical questions:

Research Question 1: How do current CQM practices impact project outcomes in the construction industry?

This question seeks to understand the baseline state of CQM in stormwater network projects, identifying existing limitations and challenges.

Research Question 2: How is the integration of AI in CQM perceived in terms of its effectiveness and potential to improve construction project outcomes such as defect reduction, cost overruns, and schedule adherence?

This question evaluates the effectiveness of existing CQM practices and the potential of AI to enhance these practices, thereby positively affecting project outcomes.

Research Question 3: What are the challenges and concerns associated with implementing AI in Project Quality Management, and how do they impact the future adoption of AI in this field?

Expected added value

This research employs a case study approach to investigate the moderating role of Artificial Intelligence (AI) in the relationship between CQM practices and construction project outcomes, explicitly focusing on infrastructure projects such as the Jeddah Stormwater program “JSWP”. This approach is essential within the context of the Saudi construction industry, where case studies are minimal. By examining the Jeddah Stormwater program, the research will provide in-depth insights into how AI technology such as machine learning, and computer vision, can transform CQM practices within a real-world construction project. The findings of this case study will be precious for several reasons:

- **Filling the Gap:** Through in-depth case analysis, the case study will contribute to the limited research examining the Saudi construction sector.
- **Enhanced Practical Knowledge:** Practitioners, especially within the Saudi construction industry, will gain crucial insights into how AI can be leveraged within their specific quality management workflows, going beyond the general recommendations often found in reviews.
- **Targeted Strategies:** The research will uncover challenges and opportunities specific to the Saudi context, aiding in the development of effective AI implementation strategies for the industry.
- **Improved Project Outcomes:** Ultimately, this research aims to contribute to consistently achieving high-quality construction projects, reduced costs, and enhanced stakeholder satisfaction through using AI in quality management.
- **Jeddah Stormwater Program Model:** The Jeddah Stormwater Program “JSWP” could be a potential model for implementing AI-enhanced CQM practices in future Saudi construction projects.

Research Objectives

Given the potential benefits of AI in improving construction project outcomes through enhanced quality management, this research aims to explore the moderating role of artificial intelligence in improving the effectiveness of quality management practices in construction projects. The study will focus on infrastructure projects as they are typically complex and involve multiple stakeholders, playing a crucial role in driving economic growth, improving quality of life, and fostering long-term sustainability in the Saudi Arabian construction industry. The specific objectives of the study are:

1. **Comprehensive Review:** Conduct a comprehensive review of empirical studies that investigate the impact of AI on construction CQM practices and project outcomes, aiming to synthesize key findings and identify gaps in the current literature.
2. **Current state of quality:** Assess the current CQM practices in JSWP and identify critical challenges and areas of possible improvement.
3. **Examine the moderating role of AI:** Investigate the relationship between CQM practices and project outcomes, focusing on AI's moderating role in translating CQM capabilities into tangible improvements. This will be achieved by gathering data from selected contractors and surveying approximately 100 project stakeholders within JSWP projects.
4. **Identify challenges:** Based on insights gathered from the selected contractors, identify and analyze the challenges associated with implementing AI-driven CQM practices in infrastructure projects (construction).
5. **Explore future opportunities:** "Explore emerging opportunities for AI to enhance CQM practices in infrastructure projects further and outline future research directions based on the findings from the study.

Hypothesis

In the rapidly evolving construction industry, CQM is essential for ensuring both the success and sustainability of projects. With the ongoing development of Artificial Intelligence (AI), there is significant interest in leveraging its capabilities to enhance the efficiency, accuracy, and overall outcomes of CQM practices. Through this approach, the study aims to offer a comprehensive analysis of AI's role in refining CQM processes and its broader implications on the efficiency and success of infrastructure projects, particularly in stormwater network management. The following hypotheses have been formulated to guide this investigation:

Hypothesis 1A: Projects that utilize comprehensive CQM practices, such as regular quality audits and practical quality control tools, are more likely to meet or exceed quality objectives than projects with less comprehensive CQM practices.

Hypothesis 1B: The degree of management commitment to a quality culture is positively correlated with the effectiveness of CQM in achieving construction project outcomes.

Hypothesis 2A: AI-enhanced quality planning significantly reduces cost overruns and project delays in stormwater network projects compared to projects that do not utilize AI-driven planning tools.

Hypothesis 2B: The integration of AI in quality assurance processes leads to higher compliance with project and quality standards in stormwater network projects.

Hypothesis 2C: AI-driven quality control tools are more effective in identifying and rectifying construction defects in stormwater infrastructure, leading to a decrease in both the frequency of cost overruns and the extent of schedule delays associated with defect rectification.

Hypothesis 2D: AI-enhanced quality improvement processes significantly enhance the effectiveness of corrective and preventive actions in stormwater network projects, leading to greater infrastructure resilience and reduced maintenance costs.

Hypothesis 3A: The main challenges anticipated in implementing AI for CQM, such as funds, data availability, and lack of expertise, negatively correlate with the current use of AI tools in CQM practices.

Hypothesis 3B: Project managers' concerns regarding the use of AI in CQM, such as transparency and ethical considerations, are negatively correlated with their perceived potential of AI to revolutionize CQM practices in the future.

Hypothesis 3C: There is a positive correlation between the perceived potential of AI to revolutionize CQM practices and the willingness of project managers to integrate AI in their CQM processes.

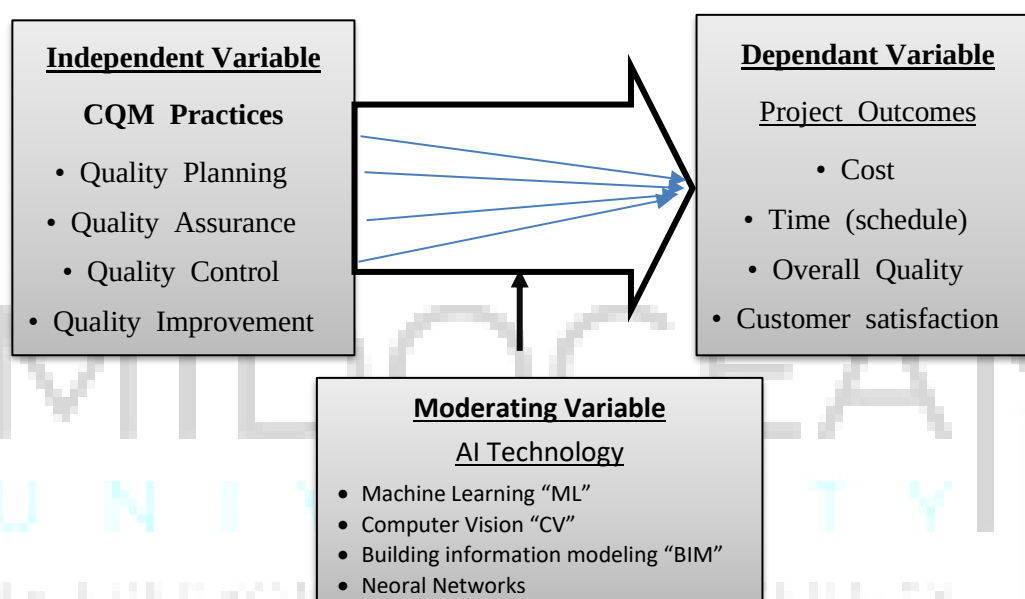


Diagram represent the variables and their relationships

Source: prepared by the researcher

Literature review

The construction industry has the potential to significantly benefit from the integration of artificial intelligence (AI) to improve quality management and project outcomes. The following table lists the literature on quality management, construction project outcomes, and the application of artificial intelligence in the construction industry, to establish a comprehensive understanding of the existing knowledge and identify gaps in the literature for this research.

<u>No</u>	<u>Title</u>	<u>Author</u>	<u>Year</u>	<u>Literature Summary</u>	<u>Researcher Comments</u>
1	Artificial intelligence and machine learning applications in the project lifecycle of the industry: A comprehensive review	Datta, S D et al	2024	The paper thoroughly assesses how AI and ML can be effectively integrated across various phases of a construction project's life cycle. Also how AI and ML can revolutionize the construction industry by enhancing productivity, reducing cost overruns, improving site safety, and optimizing project management efficiency.	The paper did not mention the use of AI in quality planning during the planning stage of the project. Also, the lack of focused investigation into how AI can enhance quality management practices in construction provides a unique angle for the study.
2	Artificial Intelligence and Its Impacts on Project Management	Reddy Nagireddy, Sindhu	2023	The paper investigated how AI can be integrated into PM practices, concluding that AI can improve project planning, resource allocation, risk management, and decision-making.	AI tools can improve the accuracy of project forecasting, perform repetitive tasks, and enhance decision-making through predictive analytics and data-driven insight. But it did not address the explicit connection between AI technologies and their direct impacts on quality management in construction projects.
3	A Qualitative Study on Artificial Intelligence and Its Impact on the Project Schedule, Cost and Risk Management Knowledge Areas as Presented in PMBOK®	Friðgeirsson et al.	2023	This paper focuses on the impact of AI on PMBOK's area of knowledge, cost, risk, and schedule. The research shows that AI has potential benefits in these areas, particularly where historical data and repeated tasks are involved	The implications of AI in cost, risk, and schedule management could indirectly influence quality management by improving overall project control and precision, which are essential for maintaining quality standards. Showing that there is a gap in studying how to integrate AI into CQM
4	Investigating AI Applications in Construction Industry: A Systematic Review	Seyman-Güray, T	2023	This study examined AI's contributions to handling challenges in the construction industry, such as cost overruns, delay, risk, rework, and safety issues. The construction industry's characteristic resistance to new technologies is noted as it is among the least digitized sectors.	this paper provides a broad overview of AI's application in the industry. There is considerable potential for transformative impacts through AI in project monitoring, and enhanced decision-making, but does not focus deeply on quality management practices, emphasizing the gap in direct studies linking AI with CQM in construction projects.
5	Mapping Two Decades of AI in Construction Research: A Scientometric Analysis from the Sustainability and Construction Phases Lenses	Regina et al.	2023	The paper investigated the effect of AI technology on improving sustainability, productivity, and efficiency. AI technologies such as machine learning, deep learning, and big data can affect construction projects' performance and digitize and modernize the construction industry, consolidating its processes and practices toward a more sustainable future.	The study suggests a growing trend towards integrating AI more comprehensively across all construction phases and deeper into sustainability practices. It provides broad understanding of how AI is applied in the industry but does not focus on quality management, and encourages ongoing innovation and research to overcome existing barriers to AI adoption in construction

<u>No</u>	<u>Title</u>	<u>Author</u>	<u>Year</u>	<u>Related Literature</u>	<u>Researcher Comments</u>
6	A Comprehensive Literature Review of Research Trends of Applying AI to Construction Project Management	Merdžanović et al.	2023	This research investigated how AI affects construction project management, including planning, scheduling, monitoring, execution, and controlling. It emphasizes how AI can automate routine tasks, improve decision-making through data analytics, and optimize project outcomes by enhancing efficiency and accuracy.	This paper provides a foundational understanding of AI's impact on construction project management but does not delve deeply into quality management practices. While it covers AI's role in enhancing project efficiency and decision-making, the direct effects on quality management are not specifically addressed, which presents a gap.
7	Adoption of Artificial Intelligence for Optimum Productivity in the Construction Industry	Victor	2022	This study focused on bridging the gap between AI and its advantages in the construction industry by reviewing several case studies. It also explores how AI and people should interact and the degree of human trust in AI technology.	The paper emphasizes AI's role in automating processes, improving efficiency, and aligning with lean principles, which prioritize reducing waste and increasing value. A significant part of the study discusses the level of trust between humans and AI systems as a critical factor for successful AI integration.
8	Digital technology for quality management in construction: A review and future research directions	Luo et al.	2022	The research investigated digital- technology that can be used to enhance CQM. Results found enhancement in detecting concealed works and preventive and post-completed defects.	This paper directly tackles the theme of digital technologies in quality management, including the use of AI. It provides a clear connection between digital technology applications and the enhancement of quality management processes illustrating both current capabilities and gaps in technology application within the scope of construction quality management, highlighting opportunities, but not relating those benefits to project outcomes.
9	An investigation into the Impact of Artificial Intelligence on the Future of Project Management	Alshaikhi & Khayyat	2021	This paper discussed the effect of using AI in PM; it highlights several AI tools and applications that could support project managers by automating tasks and providing analytical insights, thus improving the overall management of projects. However, found that AI can automate tasks but cannot replace human minutes or decrease the need for human resources.	The paper provides insights into how AI could be leveraged to automate and optimize project management tasks, which could extend to quality management practices in construction. The paper acknowledges several challenges in implementing AI in project management that require attention in future research, such as data availability, integration difficulties, high costs, and the potential impact on employment due to automation.

<u>No</u>	<u>Title</u>	<u>Author</u>	<u>Year</u>	<u>Related Literature</u>	<u>Researcher Comments</u>
10	Roles of artificial intelligence in construction engineering and management: A critical review and future trends. Automation in Construction	Pan & Zhang	2021	The study notes a shift in focus from traditional expert systems to more advanced technologies like BIM, smart robotics, cloud VR/AR, IoT, digital twins, 4D printing, and blockchain technologies. The study found AI can benefit the construction industry in terms of automation, risk mitigation, high efficiency, digitalization, and computer vision. Challenges in adoption include data quality issues, integration complexities, and investment in new technologies.	This paper directly addresses the broad applications of AI in construction but does not focus specifically on quality management. It provides a solid foundation for understanding how AI technologies are currently used and how they can potentially transform the industry. This research will focus specifically on how AI can improve quality management practices within construction projects
11	Artificial intelligence in the construction industry: A review of present status, opportunities and future challenges	Abioye et al.	2021	The study explored AI applications in CE, identifying opportunities and challenges for adoption. It explored the benefits of using several AI technologies, such as CV, robotics, NLP, ML, etc. The paper offers a critical review of existing AI applications across various construction activities, highlighting how AI is being used to tackle complex problems and enhance efficiency in construction management.	AI technology uses predictive analytics, such as forecasting project delays or optimizing resource allocation and automated construction processes, enhancing precision and safety on sites. It outlines the potential and challenges of AI in construction, which can be directly relevant to this research focus on enhancing quality management through AI. However, the paper does not explore the impact on quality management practices.
12	Impact of Artificial Intelligence on the South African Construction Project Management Industry	Makaula et al.	2021	The paper explores AI's role in improving construction project management in South Africa, from planning to execution. It highlights AI's potential to enhance labor productivity and transform the job market by creating new roles. AI also improves risk management and contributes to project success through better efficiency and cost management. However, challenges such as skill gaps and high implementation costs hinder its adoption.	This paper underscores the transformative potential of AI in enhancing various aspects of project management, including indirect impacts on quality management through improved precision and efficiency. However, it does not specifically focus on quality management practices, which provides an opportunity for this research to delve deeper into this aspect, particularly how AI can be integrated to enhance quality management in construction projects.
13	The Effect of Using Artificial Intelligence on the Quality of Decision-Making in Various Organizations: A Critical Survey Study	El-Emary et al.	2020	The study aimed to investigate the impact of AI on the quality of decision-making in various types of organizations. The results showed a positive impact despite the organization's structure. It also discussed popular techniques and algorithms of artificial intelligence.	The paper provides a critical analysis of existing research, highlighting the use of various AI techniques like Neural Networks, Support Vector Machines, and Bayesian Networks to enhance decision-making accuracy and efficiency. Such an approach can be used in assessing and analyzing the data for the case study.

<u>No</u>	<u>Title</u>	<u>Author</u>	<u>Year</u>	<u>Related Literature</u>	<u>Researcher Comments</u>
14	Research on the Application of Intelligent Construction Site in Construction Site Management	Zhang, M	2020	This paper investigated the use of intelligent construction sites (information tech) to manage construction sites more efficiently, focusing on quality and safety problems by integrating information technologies like BIM, IoT, and cloud computing in construction management.	The paper provides evidence of how AI and related technologies can be utilized to minimize quality and safety issues, and the use of BIM technology to predict potential problems and improve communication among construction site personnel. However, the paper didn't link the positive impact of AI on safety and quality on project outcomes.
15	Effectiveness of Quality Management System (QMS) on Construction Projects	Neyestani	2016	This paper evaluated the impact of QMS implementation in construction projects. It found that QMS can affect customer satisfaction, cost, time, and quality. The findings emphasize that QMS implementation enhances project outcomes by systematically improving management processes. AI can further improve decision-making by providing data-driven insights, predictive analytics, and real-time feedback loops	Although the paper investigates the broader effects of QMS, including customer satisfaction and operational efficiencies, it particularly notes that QMS least affects the project scope or quality compared to other factors. This gap suggests that while QMS frameworks (like ISO 9001) standardize processes, there might be room for enhancing their direct impact on quality, which is where AI could play a transformative role and can be integrated into QMS to amplify its effectiveness, especially in quality management.
16	Rework and schedule performance: A profile of incidence, impact, causes and solutions	Hwang & Yang	2014	This paper investigated the effect of reworks on projects. It found that rework is a significant factor in schedule delays with a high occurrence rate. Root causes of reworks include design changes and poor design coordination.	The paper discusses rework's impact on schedule and cost, the underlying theme of improving quality management systems to reduce rework offers a direct link to this research. It could investigate how AI integrated into quality management systems can reduce rework and improve schedule adherence. AI could automate parts of the change management process or provide predictive analytics to foresee potential schedule or budget overruns due to rework.
17	An Empirical Study of Quality Management Systems in the Saudi construction Industry	Aichouni et al.	2014	This paper investigated the readiness of Saudi construction firms in the Hail region to implement QMS tools. The paper identifies several barriers to QMS implementation, including organizational culture, lack of commitment, and poor knowledge of quality tools among staff.	The limited use and understanding of quality management tools and techniques noted in the study suggest a gap that AI technologies could fill. AI could facilitate more widespread and effective use of these tools by making them more accessible, easier to use, and better integrated into daily operations.

<u>No</u>	<u>Title</u>	<u>Author</u>	<u>Year</u>	<u>Related Literature</u>	<u>Researcher Comments</u>
18	Factors Affecting the Performance Of Construction Projects In The Gaza Strip	Enshassi et al.	2009	The paper identifies several key factors impacting construction project performance in the Gaza Strip, including delays due to border and road closures leading to material shortages, unavailability of resources, escalation of material prices, and the lack of experienced personnel. These issues highlight the complex interplay between external economic and political conditions and internal project management challenges.	While the paper does not specifically focus on AI, the challenges it outlines—like resource availability, material cost escalation, and effective project leadership—can be mitigated through AI technologies. AI can predict material shortages or optimize resource allocation, directly enhancing project performance. Also, the paper's findings on quality factors, such as conformance to specifications and quality of equipment and materials. AI tools can enhance quality assurance processes, ensuring compliance and improving the overall material management system. This approach is part of the objectives of this research.
19	The Role of Culture as Driver of Quality Management and Performance: Infrastructure Versus Core Quality Practices	Naor et al.	2008	The study investigated the relationships between organizational culture, infrastructure, core quality management practice, and the link to performance. It provides an insightful exploration of how organizational culture influences quality management practices and overall performance. The study distinguishes between infrastructure and core quality management practices and analyzes their interactions with organizational culture in the context of manufacturing performance.	These findings can be directly relevant to this research by illustrating the crucial role of cultural factors in the implementation and effectiveness of quality management practices in construction projects. The research can find out how similar dynamics apply within the Jeddah Stormwater Program and other construction contexts, particularly how AI can be integrated to enhance these interactions and outcomes.

Research Gap

Reviewing recent studies underscores the potential of AI in the construction industry by demonstrating how AI can automate inspection processes, identify potential issues, and improve decision-making (Datta, S D et al., 2024; Nagireddy, 2023; El-Emary, 2020). AI's success in optimizing processes in manufacturing, healthcare, and finance offers strong evidence of its transformative power across industries (Abioye et al., 2021). Despite this promise, the construction industry lags in digitalization and technology adoption. This, combined with persistent challenges like productivity issues, reworks, and cost overruns (Pan & Zhang, 2021), underscores the need to investigate AI's specific impact on construction industry quality management practices.

While there is a broad understanding of AI's potential in enhancing efficiency and decision-making in construction project management, there is a noticeable gap in research focusing on how specific AI technologies, such as machine learning “ML”, neural networks, computer vision, and Building Information Modeling (BIM), directly impact quality management practices.. The use of ML and neural networks to predict issues related to quality and delays, the employment of computer vision for automated visual inspection on site, and the integration of BIM for improved planning and coordination will be considered based on the analysis of project data and the specific challenges identified in JSWP projects. To fully grasp the need for this research, it is essential to understand the state of quality management in the construction industry and its impact on project outcomes, including cost, productivity, and customer satisfaction (Friðgeirsson et al., 2023). Limitations like inconsistent quality standards, poor quality control, and a lack of management commitment to quality can hinder effective CQM implementation (Naor et al., 2008). Addressing these challenges is crucial for improving overall project outcomes and understanding how AI can help CQM practices. Therefore, this research will investigate the relationship between quality management and project outcomes by integrating specific AI technologies within the context of Saudi Arabia's construction industry, contributing to the broader goals of Saudi Vision 2030.

Research Methodology & Data Collection

This study will employ a mixed-methods approach and a case study drawing on the Jeddah Stormwater Program Masterplan (2021). The program master plan consists of 89 packages covering all of Jeddah with stormwater and underground water-lowering networks. The networks consist of primary and secondary lines, catch basins, pumping stations, and outfalls. JSWP program stakeholders include the client (Jeddah Municipality), design consultant, PMO consultant, construction supervision consultant, and contractors.

The mixed-methods approach incorporating qualitative, quantitative, and case study elements has been chosen due to the complex nature of this research question, which examines AI's moderating role in improving quality management practices and its impact on construction project outcomes in Saudi Arabia's infrastructure sector. This approach offers several benefits for gaining a holistic understanding. Firstly, it promotes triangulation, allowing for cross-validation of findings from different data sources (Creswell & Plano Clark, 2018). Secondly, these methods offer complementary strengths: The quantitative phase will analyze project data to uncover broad correlations between AI adoption, quality management practices, and outcomes.

Simultaneously, the qualitative phase, through questionnaires, will gather insights to provide context and illuminate the underlying mechanisms behind these correlations (Ivankova et al., 2006). Including a case study will allow for an in-depth examination of the phenomenon in a real-world context, further enhancing understanding (Stake, 2005). Ultimately, this mixed-methods approach aims to generate a comprehensive and nuanced understanding of AI's influence on project management and quality assurance practices within the specific context of Saudi Arabia's infrastructure sector.

Quantitative Data Collection:

- **Project Data:** Extract and analyze data from contractors' projects to assess current CQM practices and the extent of AI integration.
- **Relevant Studies:** Review existing studies to gather data on AI techniques employed, the specific CQM aspects investigated, and the observed effects on project outcomes.
- **Case Study (JSWP):** Use the data to analyze correlations between AI adoption, CQM practices, and project outcomes.

Qualitative Data Collection:

- **Questionnaires:** The questionnaire targets JSWP stakeholders such as project managers, senior professionals, quality assurance experts, and AI specialists to understand AI's impact, challenges, and opportunities in Saudi Arabia's construction industry, particularly in stormwater network projects. It aims to explore current CQM practices, identify challenges, evaluate existing methods, and assess AI's potential to improve project outcomes. The questionnaire includes sections on respondent backgrounds, current PQM practices, potential AI applications, and insights into challenges, concerns, and future AI integration opportunities. The questionnaire will include the following sections:

Section A: Project Management Background & Experience

- This section gathers basic information about the respondent, including their role, department, years of experience, education level, types of projects they work on, project scale based on budget, team size and complexity, professional certifications, and familiarity with project management methodologies.

Section B: Project Quality Management (PQM)

- This section focuses on current practices in PQM, such as Quality Control, Assurance, TQM, and Lean Quality Management. It also explores the data sources, tools, and techniques used for quality monitoring and analysis, challenges in maintaining project quality, and the influence of organizational culture on PQM.

Potential AI Applications in PQM

- This part investigates potential uses of AI in various phases of PQM, including planning and requirements analysis, execution and monitoring, and control and improvement. It queries respondents about their interest in and perception of AI's usefulness in tasks like analyzing historical data, defect identification, compliance checks, real-time monitoring, and predictive analytics.

Challenges, Concerns, Opportunities, and Future Vision

- The final section assesses important factors for implementing AI in PQM, anticipated challenges, concerns about using AI, the potential of AI to revolutionize PQM practices, and recommendations for developing and implementing AI solutions effectively.

Research Plan

Below it the initial plan that will be modified at the beginning of the second year of the program.

	Month	Detailed Plan
2 nd Year of the program	1 to 3	- Finalize the research proposal with any necessary revisions. - Conduct a comprehensive literature review to deepen the understanding of the field and refine the research questions and hypotheses.
	4 to 6	- Develop and finalize the research methodology, including data collection tools and analysis methods. - Obtain the necessary permission for the case study. - Start gathering data for the case study from JSWP
	7 to 9	- Begin data collection for the quantitative phase of the study, focusing on extracting and analyzing data from contractors' projects and relevant studies. - Start distributing questionnaires for the qualitative phase.
	10 to 12	- continue data collection and start preliminary data analysis. - Begin drafting the initial findings and results sections
3 rd Year of the program	13-16	- Complete data collection and thoroughly analyze both quantitative and qualitative data. - Refine the findings based on the analysis and develop conclusions and recommendations. - Draft the discussion section of the thesis, interpreting findings in the context of existing literature and research objectives. - Begin drafting other parts of the thesis
	17-20	- Complete the first full draft of the thesis. - Revise and refine the thesis based on feedback from the supervisor and peers.
	21-24	- Finalize the thesis, ensuring that all sections are coherent and well-integrated. - Prepare for thesis defense, including creating a presentation

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