

Final Project 1

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Project Template

Faculty of Management
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Project title

**Integrating Artificial Intelligence into Preventive Maintenance Strategies
in Fundamental Industries**

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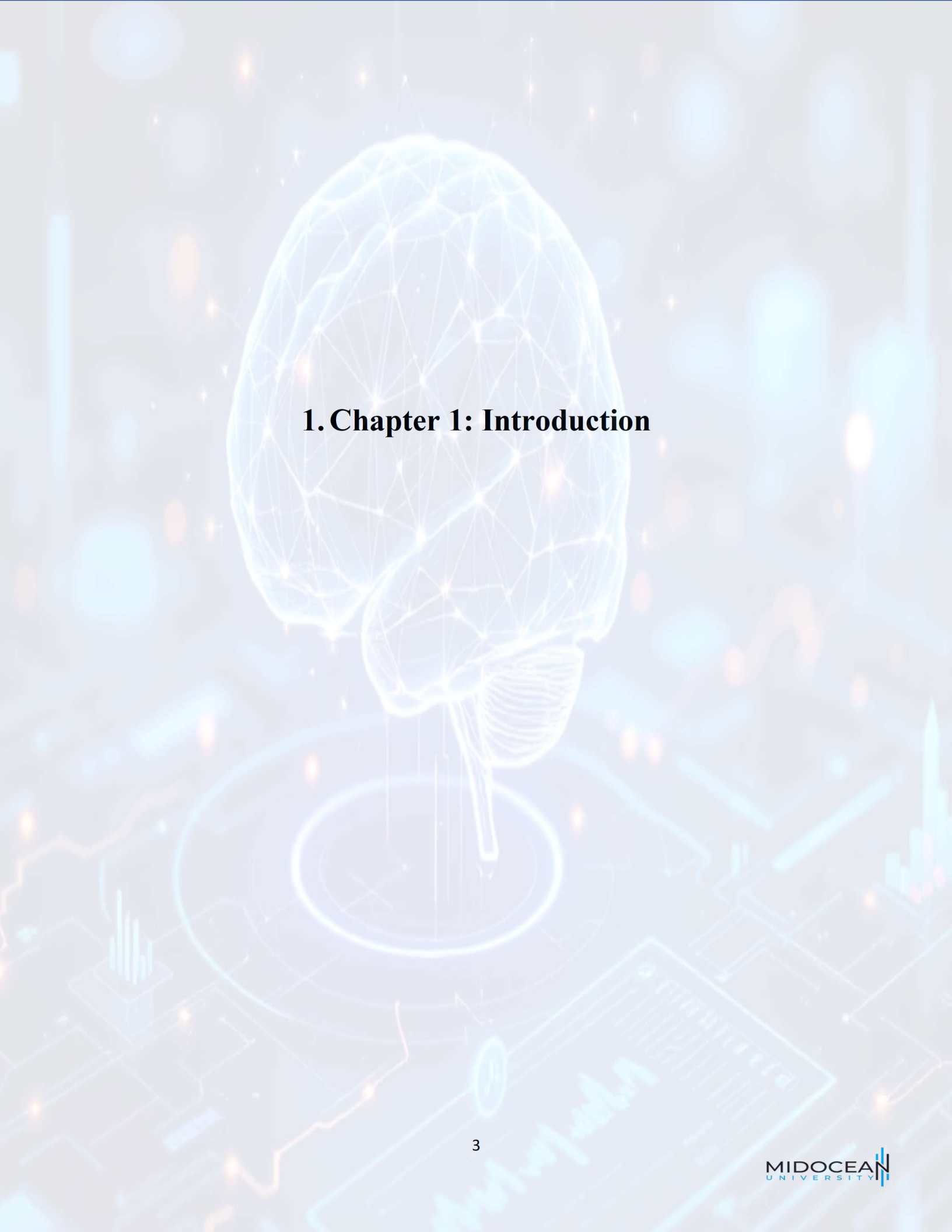
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2025 – Chapter Two

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1. Chapter 1: Introduction

1.1. Research Background

Core industries such as petrochemicals, mining, energy, and heavy materials manufacturing are increasingly challenged to maintain equipment efficiencies and to ensure that production continues without unscheduled downtimes. Preventive maintenance is an important tool in maintaining equipment in order to reduce breakdowns and improve operational performance. However, the classic approaches to maintenance are no longer keeping up with the speed of change in the manufacturing world, particularly through the Fourth Industrial Revolution, driven by innovative digital and smart technologies. Artificial Intelligence (AI) is one of the major modern technologies that is playing a bigger role in transforming maintenance. Technologies such as machine learning, predictive analytics, and the industrial Internet of Things (IIoT) rely on the real-time collection of data from operating equipment, analytics on the data, predicting failures, and determining the best timing of required maintenance before failure. This progression from traditional preventive maintenance to smart maintenance is a significant leap forward in equipping equipment with reliability (increased uptime and enhanced productivity) and significantly reduced operating costs. Many studies have been conducted in this area. Wang et al. (2021) found that the use of machine learning models improved failure-predicting accuracy, reduced unplanned downtimes by over 30%, etc. Zhou et al. (2020) studied AI improvements in real industrial settings and confirmed they enhance maintenance performance and reduce costs. Al-Mutairi (2019) stated that most industrial facilities in Saudi Arabia still apply traditional systems to capture their equipment maintenance strategies, despite high potential for shift, highlighting the desire to move to smart strategies for greater flexibility. Despite progress in scientific and technical aspects of this space, gaps remain for practical applications, particularly for Arab industrial contexts where integration of AI into maintenance systems is not without technical and organizational challenges. Accordingly, this study aims to highlight the potential and importance of AI in predictive maintenance planning by reviewing relevant literature and the proven effectiveness of smart models to improve operational performance, as well as providing a review of a conceptual and practical framework on which it can build in the future.

This study aims to bridge the gap between theoretical knowledge and practical application and to pave the way for developing modern maintenance strategies based on AI to support the sustainability of industrial operations.

1.2. Research Problem

In spite of the growth in artificial intelligence, many industrial facilities still depend on conventional methods of maintenance management. These traditional methods often lead to inadequate failure forecasting skills and increased economic cost arising from delayed issue identification or unplanned maintenance tasks. The primary research question of this investigation considers how well AI technologies improve the management of preventive maintenance planning and how barriers may be overcome to leverage these technologies in the primary industries.

1.2.1. Theoretical Gaps

Some gaps require a greater level of investigation from an academic aspect, such as:

1- There are few Arab studies linking AI to preventive maintenance planning:

In people and in relation to investing, I can't recall there being a great number of studies in an Arab industrial context linking AI applications directly to preventive maintenance planning. This might be a result of not being able to focus on the application of AI to the basic industries across the Arab world.

2- There are no theoretical frameworks that join AI model to maintenance management techniques:

While there are many studies referencing AI in terms of some generality, there are no theoretical models that join computational models, specifically linking algorithms and processes being taken, to apply tools available in maintenance management. To conceptualize a framework, which can help us reflect on how AI can factor in improving efficiency into the framework of preventive maintenance management.

3- There are no consensus of a theoretical criteria in measuring the effectiveness of AI in this space:

There is not a common basis for measuring effectiveness or effectiveness as to how AI is applied in maintenance planning. Some studies use only quantitative criteria, i.e., decreasing cost or downtime, and others are based on qualitative criteria i.e., performance or quality of work, etc. There is no clear basis approach in measuring effectiveness on how it can be measured. It is not enough just to use the rules of economics as a basis of measuring either.

1.2.2. Practical Gaps

From a pragmatic perspective, there are a variety of barriers preventing AI to be fully conceptualized as a planning tool in preventative maintenance in primary industries:

1) Too few models of success in reality, and this is especially the case in developing countries

Despite the rapid advancements AI is making, most of the deployments of AI are in 'research' or where new industrial technologies are being developed (which is still a research situation) and the absolute difference in technological infrastructures in and through developing countries creates a significant gap between these infrastructures and facility advancements.

2) Limited integration between existing maintenance infrastructures and AI-based systems

One of the tough aspects of making use of AI is the very clearly defined work to connect new systems with legacy systems. Mostly, advancing or beginning at using AI onto existing systems requires a lot of time and effort.

3) Issues arising from data collection, data analysis, data accuracy and data continuity

AI needs data. In industrial contexts, collecting data, routinely collecting data, or analysing data with any level of accuracy is not trivial. Further, necessary inaccuracy and incompleteness of data will reduce any effectiveness of intelligent systems, which will require additional strategies for the design of ways for data accuracy and quality improvements.

How effective is the use of artificial intelligence techniques in preventive maintenance planning in core industries?

1.3. Research Significance

The relevance of this study is all the more pressing in the context of the current challenges confronting core industries, which increasingly need to utilise forward-thinking technological solutions to assist with the management of preventive maintenance. The importance of this thesis rests, in part, on the potential of AI technologies to help improve the efficiency and performance of preventive maintenance in industrial facilities.

The primary objective is to identify how AI could contribute to enhancing and facilitating varying degrees of maintenance strategy, thereby reducing unplanned breakdowns, re-work and downtime and preserving resources while allowing for continuous operation.

AI is an important medium for predicting failures and improving maintenance planning. In this regard, AI represents an inflection point in the management of equipment and maintenance in industrial contexts. Not only is this study focused on exploring the application of AI technologies, it also provides a critical range of analysis on the implications of AI technology across different industries, both addressing gaps in the academic routes of research and in practice.

1.3.1. At the theoretical level

From a theoretical perspective, this study adds to the body of literature on AI in preventive maintenance management.

1- Contributing to the scientific literature on AI in maintenance management:

Generating knowledge in this area is valuable, particularly for industries that still use traditional maintenance approaches. This will allow more opportunities for academics to explore the application of AI in various contexts and sectors, such as energy, heavy equipment, transportation, etc.; also serving as valuable new references for practitioners and scholars.

2- Presenting an integrated theoretical model that shows the relationship between AI with preventive maintenance planning:

Although there are attempts to connect AI with other fields, there is lacking theoretical models/an explanation for how AI relates to preventive maintenance planning. This plan aims to present an integrated model which explains how AI algorithms have been used to predict failure and analyze operational data, providing additional insights and practical tools to incorporate.

1.3.2. At the practical level

In a practical sense, this study attempts to provide practical approaches that enhance the performance and efficiency of maintenance practices in industrial settings, amongst continuous improvement initiatives in industrial settings, in terms of cost reduction and rationalizing resource utilization.

1- Enhancing decision making with intelligent tools that will consider their analysis of data and detection of failures:

To make the right decisions regarding maintenance timings, and more importantly, when service is required through changing components or servicing, in industrial environments, time is of the essence. AI(AI) techniques such as machine learning and neural networks can augment conventional and KPI analysis tools with intelligent recommendations based on analysing a great depth of data from equipment and sensors. This scientific and intelligent analysis aid with making critical decisions, assists with increasing responsible and responsive mitigations, reduces downtimes and maintenance costs of resources.

2- Providing industrial entities with improved systems that will enhance the efficiency of maintenance operations: The study sets out to optimise preventive maintenance implementation through AI technologies. This is significant developing flexible and positive predictions regarding failures and apt times for maintenance. Thus identifying powerful systems that reduce costs, increasing efficiencies of equipment and positive efficiencies of maintenance teams that operate industrial entities. The study will provide industrial facilities with viable concepts and tools that can be used across contexts while inherently increasing sustainability of industrial operations.

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