

Mid Ocean University

College of Management

Master of Business Administration



The Role of Artificial Intelligence in Improving Production in Industries an Applied Study on Industrial Firms in Saudi Arabia

Prepared by:

Ahmed Abdulrahim Alghaythi

253000241

Supervision:

Dr. Al-Faisal Abdelhamid Mohamed Hassan

Dr. Fayez Jarad

1448-2026

DECLARATION

I hereby declare that this thesis entitled "**The Role of Artificial Intelligence in Improving Production in Industries: An Applied Study on Industrial Firms in Saudi Arabia**" is my own original work and has not been submitted, either in whole or in part, for any degree or qualification at this or any other institution.

All sources of information, ideas, figures, and quotations have been appropriately acknowledged and referenced in accordance with APA (7th edition) referencing guidelines. I also confirm that this study complies with the ethical standards governing scientific research and academic integrity.

Student Name:

Signature:

Date:

DEDICATION

This thesis is dedicated to my beloved parents, whose unconditional love, endless encouragement, and unwavering support have been the foundation of every achievement in my life.

I also dedicate this work to my family, friends, and teachers, whose guidance, inspiration, and belief in my abilities motivated me throughout this academic journey.

Finally, I dedicate this research to everyone who strives to advance knowledge and contribute to the development of industry through innovation and artificial intelligence.

ACKNOWLEDGEMENTS

First and foremost, I would like to express my deepest gratitude to Almighty Allah for granting me the strength, patience, and determination to complete this research successfully.

I would like to extend my sincere appreciation to my supervisors, **Dr. Faisal Abdul Hamid** and **Dr. Fayez Jarad**, for their continuous guidance, valuable advice, constructive comments, and unwavering support throughout every stage of this research.

My heartfelt thanks also go to the faculty members of the College of Business Administration for providing an inspiring academic environment that enhanced my knowledge and research skills.

I am deeply grateful to all managers, engineers, supervisors, technicians, and employees of the participating industrial firms in Saudi Arabia who generously contributed their time and shared their valuable experiences by participating in this study.

Finally, I would like to thank my family for their endless encouragement, patience, and unconditional support during this journey. Their confidence in me has been a constant source of motivation.

ABSTRACT

Background : In today's modern world, one of the most impactful technologies that has revolutionized manufacturing industries is Artificial Intelligence (AI). AI-assisted industrial production systems help organizations optimize processes, improve product quality, reduce production costs, increase operational efficiency, and gain a competitive edge. The implementation of Artificial Intelligence (AI) has gained momentum in Saudi Arabia, driven by the goal of digital transformation and intelligent manufacturing within the framework of Saudi Vision 2030. Saudi Vision 2030, which focuses on digital transformation and intelligent manufacturing, has seen an increase in the adoption of Artificial Intelligence (AI) in Saudi Arabia.

Aim : The objective of this study was to examine how Artificial Intelligence affects production efficiency, operation performance, product quality and reduction of production costs in the industrial sector of the Kingdom of Saudi Arabia (KSA).

Methodology : This study was conducted with quantitative research methods and cross-sectional survey design. The data were gathered using a structured questionnaire sent to the managers, engineers, supervisors and technical staff of industrial firms in Saudi Arabia. A simple random sampling procedure was used, and 150 questionnaires were used for statistical analysis. The data obtained were analyzed using descriptive statistics, Cronbach's Alpha, Pearson correlation analysis, multiple regression and analysis of variance (ANOVA).

Results : The results indicated that industrial companies in Saudi Arabia are highly adopting AI. The statistically significant positive effects of Artificial Intelligence on the production efficiency, operational performance, product quality and reduction in production costs were exhibited. The dependent variables had the highest mean score for the operational performance. Based on the regression analysis results, it was found that Artificial Intelligence accounted for about 70.9% of the variance in production improvement, thus showing that AI has a significant contribution in the manufacturing performance.

Conclusion : The study has found that Artificial Intelligence has emerged as a strategic organizational competence, significantly improving manufacturing performance. AI plays a role in intelligent manufacturing, operational excellence, sustainable competitiveness, and industrial digital transformation. The results support the Resource Based View (RBV), Industry 4.0 Theory and Digital Transformation Theory.

Keywords : AI, Production Improvement, Production Efficiency, Operational Performance, Product Quality, Production Cost Reduction, Industry 4.0, Smart Manufacturing, Saudi Arabia.

الملخص

الخلفية : يُعد الذكاء الاصطناعي من أهم التقنيات الحديثة التي أحدثت تحولاً جذرياً في قطاع التصنيع والإنتاج الصناعي، حيث أسهم في تحسين كفاءة العمليات التشغيلية، وتعزيز جودة المنتجات، وخفض تكاليف الإنتاج، ودعم اتخاذ القرار، وزيادة القدرة التنافسية للمؤسسات الصناعية. وفي إطار رؤية المملكة العربية السعودية 2030، شهد القطاع الصناعي توسعاً ملحوظاً في تبني تقنيات الذكاء الاصطناعي والتحول الرقمي، إلا أن الدراسات التطبيقية التي تناولت أثر الذكاء الاصطناعي على تحسين الإنتاج في الشركات الصناعية السعودية ما زالت محدودة.

هدف الدراسة : هدفت الدراسة إلى التعرف على دور الذكاء الاصطناعي في تحسين الإنتاج في الشركات الصناعية بالمملكة العربية السعودية، من خلال دراسة تأثيره على كفاءة الإنتاج، والأداء التشغيلي، وجودة المنتج، وخفض تكاليف الإنتاج.

المنهجية : اعتمدت الدراسة المنهج الكمي باستخدام تصميم الدراسة المقطعية (Cross-sectional Survey)، وتم جمع البيانات بواسطة استبانة وزعت على المديرين والمهندسين والمشرفين والفنيين العاملين في الشركات الصناعية السعودية. وتم استخدام أسلوب العينة العشوائية البسيطة، حيث بلغ عدد الاستبانات الصالحة للتحليل 150 استبانة. وقد تم تحليل البيانات باستخدام برنامج SPSS الإصدار 29 من خلال الإحصاءات الوصفية، ومعامل كرونباخ ألفا، وتحليل الارتباط لبيرسون، والانحدار الخطي المتعدد، وتحليل التباين.

النتائج

أظهرت النتائج ارتفاع مستوى تبني تقنيات الذكاء الاصطناعي داخل الشركات الصناعية السعودية، كما أثبتت النتائج وجود تأثير إيجابي ودال إحصائياً للذكاء الاصطناعي على كفاءة الإنتاج، والأداء التشغيلي، وجودة المنتج، وخفض تكاليف الإنتاج. وقد حقق الأداء التشغيلي أعلى متوسط حسابي بين أبعاد تحسين الإنتاج، كما أوضح تحليل الانحدار أن الذكاء الاصطناعي يفسر نحو 70.9% من التباين في تحسين الإنتاج.

الاستنتاج

خلصت الدراسة إلى أن الذكاء الاصطناعي يمثل مورداً استراتيجياً يسهم في تحسين الأداء الصناعي، وتعزيز التصنيع الذكي، ودعم القدرة التنافسية للمؤسسات الصناعية، وتحقيق أهداف التحول الرقمي ورؤية المملكة العربية السعودية 2030. كما دعمت نتائج الدراسة نظرية الموارد (RBV)، ونظرية الصناعة الرابعة (Industry 4.0)، ونظرية التحول الرقمي.

الكلمات المفتاحية

الذكاء الاصطناعي، تحسين الإنتاج، كفاءة الإنتاج، الأداء التشغيلي، جودة المنتج، خفض تكاليف الإنتاج، الصناعة الرابعة، التصنيع الذكي، المملكة العربية السعودية.

List of Abbreviations

Abbreviation	Full Meaning
AI	Artificial Intelligence
ML	Machine Learning
DL	Deep Learning
IoT	Internet of Things
IIoT	Industrial Internet of Things
ERP	Enterprise Resource Planning
MES	Manufacturing Execution System
SCM	Supply Chain Management
QMS	Quality Management System
KPI	Key Performance Indicator
RBV	Resource-Based View
SPSS	Statistical Package for the Social Sciences
ANOVA	Analysis of Variance
SD	Standard Deviation
SA	Strongly Agree
A	Agree
N	Neutral
D	Disagree
SD (Likert)	Strongly Disagree
VIF	Variance Inflation Factor
KMO	Kaiser–Meyer–Olkin Measure of Sampling Adequacy
GCC	Gulf Cooperation Council
GDP	Gross Domestic Product
ICT	Information and Communication Technology
RFID	Radio Frequency Identification

Contents

DECLARATION.....	2
DEDICATION	3
ACKNOWLEDGEMENTS	4
ABSTRACT.....	5
الملخص	6
List of Abbreviations.....	7
CHAPTER ONE	12
1.INTRODUCTION	13
1.1. Study background	14
1.2. Problem Statement	15
1.3. Research Objectives.....	19
1.4. Research Questions	20
1.5. Research Hypotheses	20
1.6. Main Hypothesis	20
1.7. Significance of the Study	21
1.8. Academic Significance	21
1.8.1. Practical Significance.....	22
1.8.2. Managerial Significance	23
1.8.3. Policy Significance.....	24
1.8.4. Economic Significance.....	24
1.8.5. Social Significance.....	25
1.9. Scope of the Study	26
1.9.1. Subject Scope.....	27
1.9.2. Geographical Scope.....	27
1.9.3. Population Scope.....	28
1.9.4. Time Scope.....	28
1.9.5. Methodological Scope.....	29
1.10. Limitations of the Study.....	29
1.10.1. Artificial Intelligence (AI).....	31
1.10.2. Production Improvement.....	32
1.10.3. Production Efficiency.....	33
1.10.4. Operational Performance.....	34

1.10.5. Product Quality.....	34
1.10.6. Production Cost Reduction.....	35
1.10.7. Industrial Firms.....	35
CHAPTER TWO	38
2. LITERATURE REVIEW	38
2.1 Artificial Intelligence and Industrial Production.....	40
2.2. Artificial Intelligence and Industry 4.0	42
2.3. Applications of Artificial Intelligence in Manufacturing.....	42
2.3.1. Predictive Maintenance.....	43
2.3.2. Intelligent Quality Control.....	43
2.3.3. Production Planning and Optimization.....	43
2.3.4. Optimizing the Supply Chain.....	44
2.4. The Role of Artificial Intelligence in the Growth of Industries.....	44
2.5. Intelligent Manufacturing Systems	45
2.6. AI Adoption in Manufacturing.....	45
2.7. Theoretical Framework.....	46
2.8. Research Gap	47
2.9. Hypotheses Development	47
CHAPTER THREE	51
3. RESEARCH METHODOLOGY.....	51
Introduction.....	51
3.1. Research Philosophy	52
3.2. Research Approach	54
3.3. Research Design.....	55
3.4. Research Strategy.....	56
3.5. Population of the Study.....	57
3.6. Conceptual Model of the Study	61
3.7. Questionnaire Development.....	62
3.8. Measurement Scale	63
3.9. Validity of the research instrument.	64
3.10. Data Analysis Methods	65
3.11. Data Collection Procedures.....	66
3.12. Ethical Considerations	67

3.13.	Data Analysis Techniques	67
3.14.	Chapter Summary	68
CHAPTER FOUR.....		70
4.	DATA ANALYSIS AND FINDINGS	70
4.1.	Response Rate.....	70
4.2.	Demographic Characteristics	71
4.2.1.	Gender Distribution.....	71
4.2.2.	Age Distribution.....	71
4.2.3.	Education Level.....	72
4.2.4.	Job Position.....	72
4.2.5.	Years of Experience.....	72
4.2.6.	Industrial Sector.....	73
4.3.	Descriptive Statistics.....	73
4.4.	Artificial Intelligence Adoption	74
4.4.1.	Frequencies and Percentages for Artificial Intelligence Adoption.....	74
4.4.2.	Percentages for Artificial Intelligence Adoption.....	75
4.4.3.	Mean and Standard Deviation for Artificial Intelligence Adoption.....	75
4.5.	Production Efficiency	76
4.5.1.	Frequencies and Percentages for Production Efficiency.....	76
4.5.2.	Mean and Standard Deviation for Production Efficiency.....	77
4.6.	Reliability Analysis.....	78
4.7.	Reliability Analysis (Cronbach's Alpha).....	78
4.8.	Correlation Analysis.....	78
4.9.	Pearson Correlation Matrix.....	79
4.10.	Multiple Regression Analysis	79
Model Summary.....		79
4.11.	Analysis of Variance (ANOVA).....	80
4.11.1.	ANOVA Results.....	80
4.12.	Regression Coefficients	80
4.12.1.	Regression Coefficients.....	80
4.13.	Hypotheses Testing	81
CHAPTER FIVE		83
.5	DISCUSSION OF FINDINGS	83

5.1.	The adoption of Artificial Intelligence.....	84
5.2.	Production Efficiency	86
5.3.	The performance of the operations.	89
5.4.	Product quality.	91
5.5.	Production Cost Reduction	93
5.6.	Research Hypotheses	94
5.7.	Implications.....	95
5.7.1.	Theoretical Implications.....	95
5.7.2.	Practical Implications.....	96
5.7.3	Managerial Implications.....	96
CHAPTER SIX.....		98
6.	CONCLUSIONS AND RECOMMENDATIONS:	98
6.1.	Summary of the Study	99
6.2.	Conclusions.....	101
6.3.	Study Contributions:	104
6.3.1.	Academic Contributions.....	104
6.3.2.	Practical Contributions.....	105
6.4.	Recommendations.....	106
6.5.	Study Limitations.....	107
7.	References.....	111
8.	APPENDIX: QUESTIONNAIRE	114

List of tables

Table 1:Measurement Scale.....	63
Table 2:Gender Distribution	71
Table 3:Age Distribution	71
Table 4:Education Level.....	72
Table 5:Job Position	72
Table 6:Years of Experience.....	72
Table 7:Industrial Sector.....	73
Table 8:Likert Scale Abbreviations	73
Table 9:Frequencies and Percentages for Artificial Intelligence Adoption	74
Table 10:Percentages for Artificial Intelligence Adoption	75
Table 11:Mean and Standard Deviation for Artificial Intelligence Adoption	75
Table 12:Frequencies and Percentages for Production Efficiency	76
Table 13:Mean and Standard Deviation for Production Efficiency	77
Table 14:Reliability Analysis (Cronbach's Alpha)	78
Table 15:Pearson Correlation Matrix	79
Table 16:ANOVA Results.....	80
Table 17:Regression Coefficients.....	80
Table 18:Hypotheses Testing Results	81

CHAPTER ONE

1. INTRODUCTION

Artificial Intelligence (AI) is one of the most transformative technologies impacting industries and manufacturing systems today. With a high rate of technological development and increasing competition in the global market, the demand for higher productivity has boosted industrial organizations to apply intelligent technologies and enhance operational efficiency, quality of products and decision making. AI is a powerful technology that can help manufacturing companies automate complex processes, analyze vast amounts of data, forecast equipment failures, streamline production scheduling, and lower operating expenses, among other benefits.

The industrial sector has seen remarkable digital transformation in Saudi Arabia, aligning with the country's Saudi Vision 2030, which focuses on technological innovation, smart manufacturing, and sustainable economic diversification. In recent years, AI technology has gained significant traction in the manufacturing sector, particularly among industrial companies looking to transform their production processes, optimize manufacturing, and enhance their competitiveness in the domestic and global markets. Despite the widespread use of AI technologies, however, there is still a lack of empirical evidence on the role AI plays in production improvement in Saudi industrial companies.

This chapter introduces the research by providing background information, research problem, research objectives, research questions and research hypotheses. It also defines the meaning and limitation of the study, clarifies some operational definitions of the key terms of the study, introduces the conceptual framework and culminates with the organization of the thesis, which serves as a basis for the following chapters.

1.1. Study background

Artificial intelligence (AI) is an important technology that impacts on all modern industrial production systems. Recent developments in machine learning, robotics, and data analytics have enabled manufacturing companies to boost productivity, optimize processes, and empower their workforce with better decision-making abilities. Another advantage of AI is the ability to handle huge volumes of data and automate complex tasks, making industrial operations more efficient and cost-effective (Jordan & Mitchell, 2015).

The Fourth Industrial Revolution (Industry 4.0) caused the speed of convergence of technologies such as AI, Cyber-Physical Systems and the Internet of Things (IoT) in manufacturing operations to accelerate considerably. In Industry 4.0, the machines can communicate with each other, track and control their own manufacturing processes to boost productivity and efficiency (Lu, 2017; Schwab, 2016).

AI can be used in manufacturing in a variety of ways, such as predictive maintenance, automated quality control, intelligent supply chain management, and production scheduling. AI predictive maintenance systems have been developed to increase machine reliability and decrease machine downtime by predictive analysing machine data to detect potential machine failures (Lee et al., 2015).

Further advancements in quality assurance processes in the manufacturing sector can be attributed to Artificial Intelligence (AI) technological advancements. Systems using AI with computer vision can detect flaws and defects in the structure of a product and help increase the overall structure and quality of a product and reduce the waste from a damaged product (Kusiak, 2018).

Furthermore, AI technologies are proving to be useful in the industrial sector for enhancing the productivity and operation of industrial enterprises. This is done by eliminating repetitive and tedious tasks. Further, AI aids in the operational decision-making process that is

reliant on data and driven by data. The adoption of AI technologies, in the industrial sector, is the most effective way of improving productivity, through optimizing the allocation of resources in the production process (Brynjolfsson et al., 2019; Acemoglu & Restrepo, 2020).

AI technologies can be used in the manufacturing industry to develop smart factories. Smart factories enable real-time regulation, real-time management of production processes, automation and predictive analytics thanks to the latest technologies. Smart factories are one of the most important aspects of Industry 4.0 and they play a key role in improving competitiveness and efficiency in manufacturing (Wang et al., 2016; Zhong et al., 2017).

Though The AI technologies have the potential to impact industrial production positively, a majority of the organizations dealing with production and manufacturing processes do not successfully integrate the AI systems due to several challenges. Technological complexity, lack of capacity caused by organizational issues and difficulties in integrating AI technologies with existing systems in production (Frank et al., 2019).

Artificial intelligence (AI) is regarded by Saudi Arabia as a key enabler for the country's economic diversification and technological innovation. Artificial intelligence (AI) technology is essential to digital transformation in all sectors. The industrial sector is a key component of Saudi Arabia's economic development plan, and the adoption of AI technologies is essential for enhancing industrial productivity and competitiveness.

What's more important, however, is that the incorporation of AI into industrial companies is essential in boosting manufacturing and operational efficiency, thereby improving the industrial development and overall economic growth.

1.2. Problem Statement

Today, Artificial Intelligence (AI) is one of the most impactful innovations of all times that is transforming industries around the globe. From improving production efficiency to automating manufacturing, from optimizing resources to ensuring product quality, to

supporting intelligent decision-making, manufacturing enterprises are increasingly implementing AI technologies. Industrial companies have turned traditional industrial production processes into intelligent production processes through advanced applications of AI, such as machine learning, deep learning, computer vision, predictive analytics, intelligent robotics, and digital twins, that allow them to adapt quickly to changes in the production process and market needs. For this reason, AI is an essential element in Industry 4.0 and smart manufacturing projects focused on increasing the competitiveness of industrial production and attaining environmentally sustainable production (Javaid et al, 2022; Bag et al, 2021).

The increasing significance of Artificial Intelligence (AI) has been a catalyst for governments and industrial associations across the globe to allocate significant resources towards developing technologies for intelligent manufacturing. The Organisation for Economic Co-operation and Development (OECD) states that AI is among the biggest contributors to productivity gains, innovation and competitiveness in the digital economy. Similarly, the World Economic Forum highlights how AI is revolutionizing manufacturing, with the potential to create autonomous production systems, predictive maintenance, intelligent quality control, and real-time operational optimization. All these developments have greatly enhanced manufacturing productivity and lowered operational costs and production downtime in most industrialized nations.

In the Kingdom of Saudi Arabia, the concept of Industrial transformation is a national priority as part of Saudi Vision 2030, a Saudi Arabian plan aimed at diversifying the economy, bolstering non-oil industries, enhancing manufacturing competitiveness, and promoting digitalization. The Saudi government has set forth several initiatives to promote the use of advanced digital technologies, such as Artificial Intelligence, automation, and smart manufacturing systems, in the industrial sector. The Saudi Data and AI Authority (SDA) and the Ministry of Industry and Mineral Resources (MoI) are continuing to advance the adoption

of AI via national strategies, innovation programs and industrial modernization initiatives. This has prompted several Saudi industrial companies to start adopting AI technologies in production planning, predictive maintenance, quality assurance, logistics management and monitoring operations.

All these advancements have not been translated into consistent implementation of Artificial Intelligence in industrial companies in Saudi Arabia. Some have made tremendous progress with the implementation of AI, but many are still facing significant challenges that make it hard to fully leverage intelligent technologies. Some of these obstacles involve the lack of digital infrastructure, high cost of implementation, lack of AI specialists, lack of employee skill, cyber security issues, resistance to technological change, and integration with the current manufacturing systems (Dwivedi et al., 2021; Frank et al., 2019). Therefore, the impact of AI on industrial production enhancement has been found to be significantly different among different entities, leading to a lack of confidence in the real effectiveness of AI in the Saudi industrial landscape.

In addition, the current body of academic research reveals some significant research gaps. Many of the empirical studies on Artificial Intelligence in manufacturing that have been carried out so far have been conducted in technologically advanced economies like the USA, Germany, China, Japan, and South Korea. All of these studies offer insights into how AI is being used in various contexts, but the results are not directly transferable to a developing economy, as there are significant differences in technological readiness, industrial infrastructure, governmental policies, workforce skills and organizational maturity. Thus, empirical studies on AI use in emerging industrial economies, such as Saudi Arabia, are needed to examine the adoption of AI in the context of rapidly growing industrial digital transformation.

One drawback that has been recognized from earlier research is the type of evaluation of AI. A large number of researchers have focused on the study of individual applications of AI such as predictive maintenance, robotics, intelligent quality management, or supply chain optimization, but none has studied the impact of AI on industrial production as it is a multidimensional entity. Operating performance is one way to measure industrial production performance, but industrial production performance has multiple aspects such as production efficiency, operating performance, product quality and production cost reduction, and these aspects are related to each other. A holistic view of AI's impact on manufacturing performance can be gained by analyzing these dimensions together.

Furthermore, previous research has focused mainly on technological aspects of the implementation of AI and paid relatively less attention to organizational perspectives. There is relatively little research on the perceptions of managers, engineers, supervisors, and technical employees who are directly involved in the manufacturing processes with AI technologies. Their practical experience in AI use makes their views integral to assessing the true impact of AI deployment, to uncover barriers to adoption, and to gauge the benefits to business from intelligent manufacturing systems. Without such considerations, the results of previous research studies are not easily applicable to industry practice and are of limited value to industrial decision makers.

Furthermore, although the use of AI technologies has been growing in Saudi industries, empirical evidence on the relationship between the implementation of the AI technologies and the improvement in production is still limited. The evidence available is limited in explaining the contribution of AI to increase the operational efficiency, operational performance, product quality, and production costs reduction of industrial companies in Saudi Arabia. The uncertainty of this lack of empirical evidence presents challenges for managers and

policymakers about the organizational outcomes of AI investments and the strategic priorities needed for successful AI implementation.

Therefore, the current study aims to fill these gaps in research by examining the use of AI to enhance production in Saudi Arabia's industrial companies. In particular, the research focuses on the effect which the introduction of Artificial Intelligence has on four key aspects of industrial production, namely: production efficiency, operational performance, product quality and reduction of production costs. The study will gather empirical data from managers, engineers, supervisors, and technical personnel from industrial companies in Saudi Arabia to achieve a complete and clear picture of how AI has been implemented in industrial production in practice and to provide evidence-based recommendations that can contribute to industrial organizations to achieve the maximum benefits of AI.

Finally, this study will have implications both theoretically and practically. It contributes to the current literature on the fields of Artificial Intelligence, Industry 4.0 and smart manufacturing in the context of emerging economies. From a practical perspective, it offers empirical evidence that could support industrial managers and policymakers in making strategic planning, investment decisions in technology, workforce development, and future digital transformation decisions to improve the competitiveness and sustainability of Saudi industrial organizations.

1.3. Research Objectives

The main objective of this research study is to concentrate on the role of AI in improving the efficiency of industrial production.

The study also aims at accomplishing the following objectives:

1. Know how Artificial Intelligence (AI) technologies impact the production efficiency in industries.
2. Analyze the impact of AI on the performance of industrial companies.

3. Identify the challenges of AI technologies to manufacturing companies.

Suggest ways to improve the use of artificial intelligence in industrial production systems.

1.4. Research Questions

The purpose of this research is to answer the following questions:

How does automation contribute to production efficiency in industry?

2. How does automation affect the workability of industrial companies?

3. What are the challenges to industrial organizations to implement automation?

4) What are the ways to enhance the use of automation in manufacturing industries?

1.5. Research Hypotheses

This research follows the theoretical basis of Artificial Intelligence, Industry 4.0, Resource-Base View (RBV), and previous empirical studies which all agree that Artificial Intelligence has a positive impact on enhancing the productive process of industries. Existing research has found that AI technologies enhance manufacturing performance by predictive maintenance, intelligent automation, production planning optimization, quality inspection, and operational decision making (Frank et al., 2019; Bag et al., 2021; Javaid et al., 2022). As such, the following hypotheses have been formulated for testing.

1.6. Main Hypothesis

H1 : There is a statistically significant positive relationship between AI and the improvement of production in industrial firms in Saudi Arabia.

In order to explore this overall hypothesis in more detail four sub-hypotheses were formulated corresponding to the four major dimensions of the production improvement.

H1a: The effect of Artificial Intelligence on production efficiency in Saudi industrial firms is seen as statistically significant positive effect.

H1b: Artificial Intelligence contributes positively to the operational performance of Saudi industrial companies with a statistically significant result.

H1c: Artificial Intelligence positively affects product quality in Saudi industrial firms, statistically.

H1d: The effect of Artificial intelligence on the reduction of production cost in Saudi industrial companies is statistically significant and positive.

The proposed hypotheses will be statistically analyzed using correlation analysis and multiple regression analysis with the Statistical Package for Social Sciences (SPSS). Based on the empirical results, one may conclude whether Artificial Intelligence plays a significant role in improving the industrial production or not, and which dimension of production has a greater influence than the other.

1.7. Significance of the Study

Artificial Intelligence is now one of the most powerful technologies assisting the transformation of industry and sustainable economic growth globally. With the increasing use of intelligent technologies in manufacturing to increase operational productivity and competitiveness, there is a growing demand for empirical research to investigate the real impact of AI on industrial production. This study is of academic importance because of its implications, practical, managerial, policy, economic and social contributions. In addition, the study contributes to Saudi Arabia's national strategy for digital transformation and industrial development in Saudi Vision 2030.

1.8. Academic Significance

Academically speaking, this research will add to the growing body of work in the field of Artificial Intelligence (AI), Industry 4.0, and intelligent manufacturing systems. In spite of the many research initiatives that have been taken by academia in the past decade, most of the empirical studies to date have been conducted in developed countries, mainly in the USA, Germany, China, Japan, and South Korea. In comparison, less empirical research has focused on the application of AI technologies in industrial organizations in developing economies of

the Middle East and Saudi Arabia. Therefore, this study helps to fill this geographical research gap by giving empirical evidence from industrial companies in Saudi Arabia.

Furthermore, most of the previous research has focused on single applications of AI like predictive maintenance, industrial robotics, quality inspection, or supply chain optimization. These studies offer significant insights into the application of certain technologies, but they don't fully capture the broader impact of AI on production. In the present study, this limitation is overcome by considering four key aspects of the industrial production, namely production efficiency, operational performance, product quality and reduction in production costs simultaneously. An analysis of these dimensions in a single integrated conceptual model gives a broader picture of how AI can be applied in a manufacturing environment (Frank et al., 2019; Dwivedi et al., 2021).

The work is also valuable to the theoretical literature, as it incorporates concepts from the Fourth Industrial Revolution (Industry 4.0), the Resource Based View (RBV) and Digital Transformation Theory. The following theories offer a full account of the process by which intelligent technologies can become strategic resources for the organization that enhance the performance of manufacturing operations and achieve a sustainable competitive advantage. Therefore, the results of this study are likely to be an input to future academic research on intelligent manufacturing and digital transformation in the new industrial economies.

1.8.1. Practical Significance

The relevance of this research is that it can be used to give useful guidance for manufacturing companies that want to enhance their production through the use of Artificial Intelligence technologies. Businesses are still spending large investment on AI implementation, but most companies still aren't sure of the real operational gains they can expect. The empirical analysis of the relationship between AI adoption and production improvement offers valuable

insights that can help industrial companies assess their technological investments and determine their priority areas for implementing AI.

In addition, the results will assist the industrial organizations in determining which industrial production dimensions gain more benefits from AI. This information allows the organization to better allocate financial resources and make appropriate decisions on technological investments, to better plan their operations, and to create plans for implementation so that they can optimize the performance of the organization while avoiding added costs.

In addition, practical recommendations for workforce development, technological readiness and organizational capability for successful implementation of AI are offered. These suggestions could help industrial companies overcome implementation hurdles and enhance the success of their digital transformation efforts.

1.8.2. Managerial Significance

Managers are central to the success or failure of the implementation of AI in industrial companies. To make informed technology investments, workforce development, process reengineering and organizational transformation decisions, empirical evidence about the outcomes of AI adoption is needed and required to be reliable. This study thus gives the managers practical proof of the role of Artificial Intelligence in enhancing production efficiency, operational performance, product quality and reduction of production cost.

The research also provides insights for managers to help them make informed decisions about implementing AI successfully in their organizations. The results can be used by managers to develop digital transformation plans, optimize production scheduling, streamline maintenance and support, reengineer processes, and increase the competitiveness of the organization. Moreover, it could help managers enhance organizational acceptance of

intelligent technologies and minimize resistance to technological change by understanding the perceptions of the employees who are tasked with implementing the technology.

1.8.3. Policy Significance

This study is not only relevant for industrial organizations, but also for governmental institutions involved in economic development, industrial modernization and digital transformation. Artificial Intelligence has been identified by the Kingdom of Saudi Arabia as one of the strategic technologies to support the Kingdom's economic diversification in line with Saudi Vision 2030. The government is supporting the use of AI in its national strategies to enhance the competitiveness of industries, increase manufacturing productivity, and foster innovation.

The empirical results from this study can help policymakers assess the impact of existing digital transformation programmes and consider further policy interventions needed to ensure faster adoption of AI in industry. The study could also contribute to the establishment of national training programs, technological infrastructures, research collaborations and innovation ecosystems that support intelligent manufacturing across the Kingdom.

Moreover, the recommendations provided by this study can be used by governmental institutions in charge of industrial development to prepare new industrial policies for the promotion of productivity and competitiveness and also support sustainable industrial development.

1.8.4. Economic Significance

The manufacturing industry is one of the most significant contributors to sustainable economic development since it is a source of employment, export, innovation and diversified sources of national income. The productivity enhancement of manufacturing has direct implication for enhancing national economic growth and competitiveness of manufacturing.

Artificial Intelligence technologies offer manufacturing companies a chance to cut down production expenses, enhance operational efficiency, shed waste, optimize resources, and boost production capacity. Such enhancements will reinforce organizational profitability and boost national industrial competitiveness in the global markets. Thus, the results of the present study help in comprehending the potential of AI technologies to support in the long-term economic development, by enhancing the manufacturing performance and thus, increasing the industrial sustainability.

Moreover, the successful application of AI in these sectors can help boost investments in Saudi industrial sectors by attracting local and international investors to join in with technologically advanced industries.

1.8.5. Social Significance

AI is not just reshaping the way industries work but is also influencing how they train their employees and learn. The implementation of AI is not only changing the way industries operate but also how they train their employees and how they learn. As AI technologies become more prevalent, there is a growing need for highly skilled workers who can manage AI-driven manufacturing systems, analyze production data, and participate in digital transformation efforts. Therefore, it is important to emphasize an ongoing training for employees, technological education and professional development in industrial organizations as stressed in this study.

Furthermore, AI-driven manufacturing is helping to enhance the safety of the workplace by minimizing employee exposure to hazardous manufacturing processes and repetitive tasks. Intelligent automation allows workers to focus on more value-added tasks that demand creativity, innovation and strategy instead of routine, operational work. This makes successful implementation of AI a key part of boosting employee satisfaction, improving organisational learning and building workforce sustainability for the longer term.

This study's most significant aspects are its direct alignment with Saudi Vision 2030, which focuses on the digitization, industrial modernization, technological innovation, and economic diversification. The Vision aims to make Saudi Arabia a world-class and leading country in the field of advanced manufacturing and intelligent technologies through the adoption of Artificial Intelligence (AI) and Industry 4.0 applications.

The study aimed to find out the contribution of Artificial Intelligence to the industrial production process in the actual world and therefore it gave empirical evidence for the national efforts to modernize the industrial production process and to increase the industrial productivity. The results can thus help industrial companies, decision makers, investments and educational institutions to formulate coordinated strategies for supporting the Saudi Arabia's transition to a knowledge-driven industrial economy that can be competitive in global markets.

The value of this study reveals that it can serve the academic community, industry practice, managerial decisions, governmental policy, the economic development, workforce improvement, and the implementation of Saudi Vision 2030. These multiple contributions again underscore the importance of exploring the role of Artificial Intelligence in enhancing production in Saudi Industrial companies and make sound arguments to support the current research.

1.9. Scope of the Study

Defining the scope of the research study is very important as it sets the limits for the research. A clearly defined scope assists the reader in understanding what the study is about, what population is being studied, the geographical area being studied, the time period being studied and the variables being included in the study. It also helps to keep the research objective attainable and enables the researcher to conduct a thorough study of the phenomenon of interest (Creswell & Creswell, 2023). For this reason, the following dimensions are considered in the present study.

1.9.1. Subject Scope

The present study aims to study the impact of Artificial Intelligence (AI) on the production of the industrial enterprises. In particular, the study examines the influence of Artificial Intelligence as the independent variable on the four dimensions of industrial production which together make up production improvement.

Artificial Intelligence Adoption is the independent variable of the research, as it is the process of implementing and using AI technologies in industrial production systems. AI adoption involves using intelligent algorithms, machine learning, computer vision, intelligent automation, predictive analytics, and data-driven decision-making to assist in manufacturing processes.

Production Improvement is represented by the four dimensions; the dependent variable.

- Production Efficiency
- Operational Performance
- Product Quality
- Production Cost Reduction

The chosen dimensions have been chosen due to their frequent appearance in the literature of industry 4.0 and smart manufacturing (Frank et al., 2019; Javaid et al., 2022). Together they offer a full picture of the contribution of Artificial Intelligence to the enhancement of industrial production.

1.9.2. Geographical Scope

This study is conducted on a geographical basis of industrial companies established in the Kingdom of Saudi Arabia. Saudi Arabia is an appropriate context, as the industrial sector is the major sector that helps in national economic diversification under Saudi Vision 2030. Moreover, Saudi industries are more and more dedicated to Artificial Intelligence, automation,

robotics, and digital transformation programs to boost productivity in manufacturing and improve their competitive standing in the global market.

By focusing the research on Saudi Arabia, the researcher can study the implementation of AI in an emerging industrial economy in the midst of rapid technological changes. As a result, the results offer industry-specific insights into the use of AI in the manufacturing sector and help to inform national industrial development initiatives.

1.9.3. Population Scope

The study's population consists of managers, engineers, supervisors, and technical staff in the industrial sector in Saudi Arabia. Employees have been chosen who are directly involved in the manufacturing process and have a practical understanding of the production systems, operational processes, maintenance activities, quality management, and implementation of Artificial Intelligence.

Technological decision-makers (managers) offer strategic insights on technology investments and organizational change, while engineers and technical staff offer practical experience with AI implementation in manufacturing contexts. Supervisors provide important insights into production planning, workflow, and daily production results. Together, they provide the most suitable group of respondents to assess the impact of Artificial Intelligence in industrial production in practice.

1.9.4. Time Scope

The present study has conducted an empirical study during the academic year 2026. During this period, data were gathered using a structured questionnaire that was applied to the employees in the industrial companies in Saudi Arabia.

This study uses a cross-sectional research design, which means that the data are collected one time at a specific time, rather than at several times over the course of the study.

The results only capture respondents' perceptions of the use of Artificial Intelligence over the past three years and are not intended to gauge shifts in organizational performance over time.

1.9.5. Methodological Scope

In terms of methodologically, the study uses quantitative research approach because in the quantitative research method, the appropriate method to analyze the relationship between variables is statistical analysis. A structured questionnaire with a 5-point Likert scale (Strongly Disagree — Strongly Agree) is used to collect data.

The data collected will be analyzed with the Statistical Package for the Social Sciences (SPSS). To analyze the proposed research hypotheses, statistical techniques are used such as descriptive statistics, reliability analysis with Cronbach's Alpha, Pearson correlation analysis and multiple regression analysis.

Since the quantitative approach allows for objective measurement of employees' perceptions and allows for hypothesis testing and statistical generalization to the target population (Hair et al., 2022), it is deemed suitable.

1.10. Limitations of the Study

The present study, like all empirical studies, is limited by a number of factors which must be considered when interpreting the findings. An awareness of these constraints increases the clarity of the study and researchers know where to proceed in future studies.

A restriction that might be pointed out is the geographic scope of the study. The study is carried out only in the industrial companies in Saudi Arabia. Therefore, the results may be affected by the unique organizational, technological, economic, and cultural factors in Saudi Arabia. Thus, it is important to be careful when making inferences about other industrial organizations in other countries with different institutional settings.

The second limitation is associated with the research design. The study design for this study is a cross-sectional survey design, which is a survey research design that gathers data at

one time. This method is common in management and industrial research, but it is not possible to observe changes in the implementation of Artificial Intelligence or production performance over time. Longitudinal studies could thus offer further insights into long-term impact of AI adoption.

Another constraint is the reliance on self-reported data from questionnaires. The study is based on perception of the respondents about the implementation of AI and the improvement of production, instead of objective indicators of organizational performance. Although confidentiality procedures encourage honest responses, some degree of response bias cannot be completely eliminated.

Moreover, the study only considers production improvement in four aspects: production efficiency, operational performance, product quality and production cost reduction. Other organizational outcomes such as innovation capability, supply chain resilience, environmental sustainability, employee creativity, customer satisfaction and financial performance are not in the scope of the present investigation and may be investigated in future studies.

Lastly, the study does not discuss AI technologies individually but rather looks at the AI as a technology capability. Research in the future could explore the specific roles machine learning, deep learning, intelligent robotics, digital twins, autonomous systems, and computer vision can play in industrial production performance.

These restrictions do not decrease the value of the study. Instead, they outline its scope and limitations and suggest opportunities for further research to broaden and deepen the knowledge of the implementation of AI in the industrial manufacturing industry.

Operational Definitions

In quantitative research, operational definitions are crucial because they provide clarity on the meaning of the variables studied and how each variable will be measured in the context of the research. Conceptual definition is a description of the theoretical interpretation of a

construct while operational definition is a description of how the construct will be interpreted and measured in the present study. Clear operational definitions increase the validity of research and make it easier to measure; also, future researchers will be able to replicate the study (Creswell & Creswell, 2023). Thus, the following operational definitions were used in this research.

1.10.1. Artificial Intelligence (AI)

Artificial Intelligence is one of the most talked about concepts in Computer Science, Information Systems and Industrial Engineering. In the last decades, many researchers came up with various proposals to define AI, for various purposes and research fields.

Artificial Intelligence is the ability of a computer system to learn, reason, plan, perceive, understand language, and make decisions, which are typically tasks of human intelligence (Russell and Norvig, 2021). Their definition highlights that they are intelligent agents which act rationally in complex environments.

In the same way, the founder of the term Artificial Intelligence, John McCarthy, stated that AI is the science and engineering of "making intelligent machines". While this classical view is still relevant, today's AI goes beyond rule-based architectures to encompass adaptive learning algorithms, which refine their capabilities over time.

According to Dwivedi et al. (2021), Artificial Intelligence refers to a set of technologies that involve machine learning (ML), deep learning (DL), natural language processing (NLP), computer vision, and intelligent automation, which allow organizations to interpret massive amounts of information, make intelligent decisions and automate complex business tasks. This definition goes beyond AI being a tech innovation to highlight its role as an organizational capability.

Similarly, according to Javaid et al. (2022), Artificial Intelligence is a technological system that facilitates the manufacturing organizations to optimize the manufacturing

processes through intelligent automation, prediction, optimization, and autonomous operational decision making. They are concerned only with the use of AI in industrial settings.

While each of these definitions puts a slight emphasis on a different aspect of the definition, all agree that Artificial Intelligence allows computers to emulate the cognitive capabilities that humans once performed and constantly enhance their function based on learning and experience.

Operational Definition

In this study, Artificial Intelligence is used in relation to the extent of use and implementation of intelligent technologies (such as machine learning, intelligent automation, predictive analytics, computer vision, and data-driven decision making) in industrial production processes in order to enhance them. It is assessed by employees' sentiment on the introduction and application of AI tools in their companies.

1.10.2. Production Improvement

Production improvement is a multidimensional term that means continually improving manufacturing systems to make them more efficient, better, cheaper, and more productive.

According to Slack et al. (2022), production improvement refers to the systematic improvement of the manufacturing activities by optimizing the usage of resources, continuous improvement of the manufacturing process, and achieving operational excellence.

Production improvement, according to Heizer, Render, and Munson (2023), is considered within the context of organizational efforts to improve manufacturing effectiveness while at the same time minimizing production waste, delays, and production costs.

Production improvement in Industry 4.0 environment is primarily through intelligent technologies that can optimize manufacturing operations, enhance decision quality and increase production flexibility (Javaid et al., 2022).

The above definitions suggest that production improvement is a more holistic organizational achievement, not just an operational measure.

Operational Definition

The term "Production Improvement" in this study is used to denote the overall improvement in the manufacturing performance due to implementation of Artificial Intelligence. It is depicted in four dimensions:

- Production Efficiency
- Operational Performance
- Product Quality
- Production Cost Reduction

1.10.3. Production Efficiency

Among all the measures of manufacturing performance, production efficiency is one of the most significant as it indicates the degree of efficiency of the organization to produce as much output as possible using as little resources as possible.

Production efficiency refers to the ability of a manufacturing system to produce maximum output with minimum amounts of labor, materials, energy and production time, as described by Heizer et al. (2023).

Production efficiency is defined as the efficiency of using organizational resources to obtain the desired production target without wasting operations, according to Slack et al (2022).

According to the researchers Javaid et al. (2022) AI enhances the efficiency of production by optimizing production scheduling, minimize production downtime, optimize equipment utilization, and facilitates intelligent production planning.

Operational Definition

Production Efficiency measured in this study is the perception of the employees on how AI technology increases the productivity of the manufacturing, utilization of equipment, production schedule and overall production output.

1.10.4. Operational Performance

Operational performance is the efficiency of the manufacturing process in meeting the business goals.

As described by Slack et al. (2022), the operational performance is defined as an organization's ability to carry out the manufacturing activities efficiently and at a high quality, flexibility, speed, reliability, and cost.

According to Frank et al. (2019), operational performance is a measure of the overall effectiveness of the production systems in order to meet the organizational goals through efficient workflow, resource management and intelligent operational control.

Operational Definition

Operational performance in this study is the effectiveness perception of manufacturing performance when implementing Artificial Intelligence, including production planning, monitoring of manufacturing operations, decision making, coordination of workflow, and manufacturing productivity.

1.10.5. Product Quality

The quality of a product has been one of the most important metrics of manufacture excellence.

David A. Garvin (1987) has defined product quality as the degree to which a product meets customer requirements and meets the technical requirements.

According to Kusiak (2018), the use of Artificial Intelligence (AI) can enhance the quality of products by facilitating intelligent quality inspection, automated detection of defects and ongoing monitoring of the process.

Operational Definition

In the context of the present study, product quality is defined as the employee's perception of the degree to which Artificial Intelligence enhances the accuracy of the manufacturing process, defect identification, quality control process, and adherence to the organization's quality standards.

1.10.6. Production Cost Reduction

Production cost reduction denotes the reduction of production costs without reducing the production performance.

Reducing costs is taking steps to lower operational costs by using the production in an efficient way, by eliminating waste, by making continuous process improvements, according to Heizer et al. (2023).

According to Javaid et al. (2022), Artificial Intelligence helps in lowering production cost by predictive maintenance, intelligent scheduling, resource optimization and less downtime of operations.

Operational Definition

In the context of this study, production cost reduction is the degree to which Artificial Intelligence can help to cut down on the maintenance cost, the loss from production, downtime of equipment, waste of resources, and boost the profitability of the organization.

1.10.7. Industrial Firms

Industrial firms are companies involved in manufacturing processes that convert raw materials into finished goods (goods that are intended for sale) in an organized manner.

Industrial companies include those in the food processing, chemicals, petrochemicals, metals, machinery, electronics, and other industries that produce goods. (According to the United Nations Industrial Development Organization)

Operational Definition

The subject of this research is the industrial companies located in the Kingdom of Saudi Arabia and those companies are defined as manufacturing industries, and the research population is the managers, engineers, supervisors and technical employees of these companies. These organizations are, or are currently implementing, AI technologies to aid in their industrial production activities.

Chapter summary

The current research has been built up on the concept of Artificial Intelligence and its increasing significance in revolutionizing industrial production systems, which was introduced at the beginning of this chapter. The chapter provided the background of the study, and highlighted the growing use of Artificial Intelligence technologies in manufacturing companies, highlighting the importance of the industrial transformation of Saudi Arabia under the Saudi Vision 2030. It also highlighted the research problem by showing the lack of empirical evidence in the literature about the role of Artificial Intelligence in enhancing production in the industrial companies in Saudi Arabia and thus justifying the necessity of this study.

In addition, the research questions, objectives, and hypotheses used in the study were presented, and the academic, practical, managerial and policy relevance of the study was fully explained. The scope and limitations of the study were clearly defined to fix the boundaries of the study and the operational definitions were used to explain the meaning of the principal variables studied. Furthermore, the conceptual framework showed the proposed relationships between Artificial Intelligence and the four dimensions of the production improvement such as

production efficiency, operational performance, product quality, and reducing production costs. Finally, the organization of the thesis was outlined and the purpose for each chapter explained.

In general, the whole study was developed on the theoretical and conceptual basis of Chapter One. It provided a clear context of the research, provided some justification for the need to study Artificial Intelligence in Saudi industrial firms, and presented the conceptual model that was followed in the empirical study. On this basis, the next chapter reviews the literature in a comprehensive manner, including the literature of Artificial Intelligence, Industry 4.0, intelligent manufacturing systems, production improvement, and previous empirical studies. It also formulates the theoretical framework that underlies the research, and defines the research gap that is resolved by the present research.

CHAPTER TWO

2. LITERATURE REVIEW

Artificial Intelligence (AI) has become one of the most game-changing technologies of the 21st century that is reshaping how industrial organizations design, manage and optimise their production processes. Manufacturing companies have been able to transcend the conventional manufacturing process and transition to the intelligent manufacturing method with the rapid development of AI technologies such as machine learning, deep learning, computer vision, natural language processing, robotics and predictive analytics, which rely on data and intelligence. In the era of growing competition and changing customer expectations, the use of AI is becoming more common in industrial organizations to boost the operational efficiency, product quality, reduction of production cost and sustainable competitive advantage (Dwivedi et al., 2021; Javaid et al., 2022).

Artificial Intelligence is on the rise in manufacturing industries in the era of Industry 4.0. Industry 4.0 is the fourth industrial revolution, where digital technologies, cyber-physical systems, Internet of Things (IoT), cloud computing, big data analytics and Artificial Intelligence (AI) are being introduced into manufacturing processes. These technologies allow industrial companies to set up production systems that enables the real-time communication, decision autonomy, predictive maintenance, intelligent quality control and continuous optimization of the operational system (Frank et al., 2019). Therefore, Artificial Intelligence has transformed from a technological support tool to a strategic organizational ability that has a great impact on manufacturing performance and organizational competitiveness.

AI has become a vital tool for production automation and is also vital to strategic decision-making, an element that is gaining increasing awareness among industrial organizations around the world. Manufacturing systems equipped with artificial intelligence continuously gather and analyse production information, detect inefficiencies, anticipate

equipment breakdowns, plan production schedules and enhance supply chain coordination. These functions allow companies to optimise productivity without wasting resources, time and effort in production and maintenance. Thus, AI has emerged as an important factor in the smart manufacturing and digital industrialization (Bag et al., 2021).

In the Kingdom of Saudi Arabia, the significance of Artificial Intelligence (AI) has increased significantly since the introduction of Saudi Vision 2030, which focuses on economic diversification, industrial modernization, digital transformation, and technological innovation. Promoting the industrial sector's competitiveness and sustainable economic growth, advanced manufacturing technologies, intelligent automation, robotics, and the applications of Artificial Intelligence in industrial processes have been encouraged with the help of government programs. In Saudi Arabia, the use of AI technologies has become increasingly common in the production process to boost production efficiency, optimize production processes, improve product quality and lower the production costs. Despite all these developments, empirical studies that focus on evaluating the actual performance of AI applications with regard to production improvement in Saudi industrial companies are still limited, which makes this study significant due to the gap it fills in the research field.

The study of Artificial Intelligence (AI) has received extensive attention in previous studies, both from technological, organizational, and operational angles. The applications of AI in predictive maintenance, intelligent manufacturing systems, production scheduling, quality management, supply chain optimization, autonomous robotics, and industrial automation have been explored. Many studies have found AI implementation and organizational performance to have positive correlations. But most studies examined only specific AI technologies or specific aspects of manufacturing performance rather than Artificial Intelligence as an organizational capability that can affect various aspects of production improvement simultaneously.

Moreover, most of the empirical data are from developed economies and the literature on Saudi industrial organizations is comparatively low.

To fill this, the current study focuses on four integrated dimensions which include production efficiency, operational performance, product quality and production cost reduction using Artificial Intelligence. The study examines these dimensions simultaneously to capture the overall picture of the role of Artificial Intelligence in the Saudi industrial sector in improving manufacturing performance. Furthermore, the theoretical framework of the study is based on the Resource-Based View (RBV), the industry 4.0 Theory, and Digital Transformation Theory, which explain how Artificial Intelligence can improve organizational performance.

The theoretical and empirical background of the study is given in this chapter. It starts with an overview of the concept, features, development and uses of Artificial Intelligence. The chapter then explores how Artificial Intelligence relates to Industrial Production and introduces Industry 4.0, intelligent manufacturing systems, and applications of Artificial Intelligence in manufacturing. Later, the chapter discusses the aspects of production improvement, such as production efficiency, operational performance, product quality and production cost reduction. Afterwards, theoretical perspectives that underlie the study are introduced, followed by a detailed review of existing empirical studies, identification of gaps in previous studies, and formulation of a conceptual framework that underlies the current study.

Overall, this chapter sets the theoretical foundation for comprehending the role of Artificial Intelligence in the industrial production. It reflects the existing academic knowledge, critically appraises the previous empirical studies, pinpoints the research gaps and gives the conceptual basis of the research hypotheses and empirical analysis stated in the next chapters.

2.1. Artificial Intelligence and Industrial Production

In today's world, one of the biggest technological facilitators of change in the modern industrial production system is Artificial Intelligence (AI). With the use of AI, the Modern

Industry has the potential to increase productivity, automate processes, and improve the company's operational decision-making. AI has the potential to revolutionize manufacturing by providing the ability to automate advanced decision-making and operational processes. Moreover, AI possesses advanced computational algorithms that can parse and analyze considerable amounts of manufacturing data and use the data to identify patterns in order to optimize operational processes (Jordan and Mitchell, 2015).

Production firms use sensors, machines, and production tracking systems to monitor systems and generate data. AI has the capability to parse and analyze data in real time and offer treatment options to management to allow for the optimization of production, the reduction of operational inefficiencies, and the improvement of the entire system. With AI Analytics, manufacturing firms can reduce their need for operational decision-making (Dwivedi et al). This means the ability of the firm to conduct operational predictive analytics increases. With AI, manufacturing firms can conduct operational decision-making with predictive analytics (Dwivedi et al).

One of the major movements in the Industrial Manufacturing Process with the use of AI was to eliminate the need for human involvement in processes, or to delegate the human involvement to a lesser role. With the use of AI, machines can be used to perform the monotonous processes that were previously conducted by a human and do so with greater speed, efficiency and accuracy (Davenport and Ronanki, 2018).

Workforce productivity within the manufacturing sector can also be complemented by the utilization of artificial intelligence. The introduction of AI technologies means employees can relinquish mundane tasks and concentrate on higher-order tasks that include strategic thinking, innovation, and process-improvement activities. Such changes in the roles of employees not only lead to the increased productivity of an employee but also improved performance of the organization as a whole (Acemoglu & Restrepo, 2020).

2.2. Artificial Intelligence and Industry 4.0

The continuous advancement of artificial intelligence technologies has been parallel with the development of the Fourth Industrial Revolution, otherwise known as Industry 4.0. This refers to a new era of industrial production that combines digital technologies of artificial intelligence, the Internet of Things (IoT), big data, and robotics with traditional cyber-physical systems in manufacturing (Schwab, 2016).

The Fourth Industrial Revolution (Industry 4.0) fosters a new culture of smart manufacturing whereby machines, sensors, and digital systems communicate with one another in real time to increase production efficiency. Smart systems give manufacturing companies the ability to conduct continuous production monitoring, identify process breakdowns, and perform automatic adjustments to the process (Lu, 2017).

One of the most crucial parts of Industry 4.0 is cyber-physical systems. These systems combine the use of physical manufacturing machinery with a digital control system that allows for the monitoring and control of the processes in real time. Among the most critical components of these systems is the use of artificial intelligence (AI), which helps control processes in a production facility and allows machines to adapt and make decisions autonomously with respect to variable production factors (Lee et al., 2015).

The combination of artificial intelligence with 4th Industry technologies fosters the emergence of smart factories. These are manufacturing systems with a high level of automation, where intelligent systems and technologies are used to refine and enhance production processes. Smart factories are able to better use their resources (Wang et al., 2016).

2.3. Applications of Artificial Intelligence in Manufacturing

AI technologies are vital for the development of manufacturing systems. They have a wide range of applications, which have a considerable effect on productivity, quality, and efficiency of operations.

2.3.1. Predictive Maintenance

AI-assisted predictive maintenance is a vital application of artificial intelligence in production. AI predictive maintenance systems are able to assess the performance of machinery in order to predict its failure. These systems are capable of recognizing the warning signs of a malfunction, and as a result, the downstream system undertakes maintenance operations in the order of priority (Lee et al., 2015).

Predictive maintenance systems are capable of decreasing machine downtime, increasing the reliability of equipment, and decreasing the costs associated with maintenance. This allows manufacturing companies to improve operational performance and increase production.

2.3.2. Intelligent Quality Control

Another area where artificial intelligence has made huge improvements is the quality control process in the manufacturing sector. Traditionally, quality control relied on either manual inspection of quality control or automated systems that were prone to faults or defects. Now, many manufacturers use AI and computer vision to eliminate defects in the production process. Using machine learning and computer vision, manufacturers can examine and analyze images of parts and detect defects that the human eye would miss (Kusiak, 2018). With the advent of intelligent quality control systems, manufacturers can improve quality, reduce waste, and improve the quality of the customer's experience.

2.3.3. Production Planning and Optimization

The application of artificial intelligence in production planning and production process optimization is particularly important based on the application of sophisticated analytical methods on the various available data sets related to production activities, resource utilization, and demand forecasting.

The optimization algorithms based on AI technology have enabled production companies to identify the optimal ways of developing production schedules, the optimal ways of resource utilization, and the optimal ways of minimizing the operational inefficiencies. It has been proven that the implementation of all of the above strongly positively affects the results of productive activities in the field of manufacturing and leads to the minimization of expenses related to production (Frank et al., 2019).

2.3.4. Optimizing the Supply Chain

As for the manufacturing industry, artificial intelligence (AI) has made significant contributions to the advancement of supply chain management. AI provides tools that help in the analysis of supply chain data to anticipate demand fluctuations, evaluate and optimize inventory, and improve the logistics.

AI tools strengthen the supply chain management in the event of disruptions to production. The latest digital technologies improve the analysis of supply chain risk and empower companies to identify and mitigate risks in the supply chain before they materialize. (Ivanov et al., 2019).

2.4. The Role of Artificial Intelligence in the Growth of Industries

Artificial Intelligence improves the productivity of industries by enhancing the efficiency of operations and automating the production of goods. AI technologies in organizations improve the employment of resources, the reduction of waste in the production processes, and the quality of the operational decision-making.

The positive effects of AI adoption on productivity have been demonstrated. AI technologies empower organizations to analyze and improve the production processes and automate the performance of complex tasks (Brynjolfsson et al., 2019). Analytics for AI technologies provide organizations with the ability to improve strategic decision making and the operational efficiency of the organization.

Additionally, artificial intelligence technologies enhance productivity in the workforce through human-machine partnerships in the industrial arena. Such partnerships enable organizations to use the advantages of human intelligence and machine learning (Rai et al., 2019).

2.5. Intelligent Manufacturing Systems

Intelligent manufacturing systems are considered among the highly developed offerings of actually utilizing AI technologies in the industrial production sector. Intelligent manufacturing systems combine AI, robotics, digital technologies, and analytics to create smart manufacturing systems that can function independently.

Intelligent manufacturing systems provide the ability to collect, review, and analyze operational data of all systems within an industrial firm and automatically modify the parameters of all manufacturing systems. Such systems can provide improved operational efficiency and enhanced flexibility for the firm. Improved efficiency and flexibility can be obtained in shorter time frames. These systems can also provide the ability of the firm to quickly adapt to the frequent changes in market demand and the changes in production systems resulting from the technological advancements. This ability provides improved operational efficiency and enhanced flexibility in the shorter time frames.

2.6. AI Adoption in Manufacturing

Although the application of artificial intelligence technologies provides multiple benefits, manufacturing firms encounter various limitations and barriers within AI systems. A fundamental obstacle is the amount of money that needs to be spent to be able to utilize the technology of artificial intelligence. The accompanying costs of sophisticated digital technology, cutting-edge computer systems, and the training of workers must be accounted for in order to incorporate various AI systems.

The second obstacle is the lack of available personnel who have the needed training in artificial intelligence and data analytics. Manufacturing companies have a hard time finding workers with the skills needed to develop and operate AI-based production systems (Bag et al., 2021).

Integrating AI-based production systems and already existing production systems is the final obstacle discussed. The degree of organizational restructuring and the transformation of production processes that are needed to enable the smooth integration of AI systems is often overlooked.

2.7. Theoretical Framework

This study's theoretical foundation is the combination of several theoretical viewpoints pertaining to technological innovation and the digital transformation of manufacturing industries.

A significant part of the foundation deals with the Fourth Industrial Revolution theory, which describes the impacts of AI, robotics, and cyber-physical systems on industrial production systems (Schwab, 2016). It describes how advanced digital technologies are synergistically applied to an organization that can create intelligent production systems that improve productivity and efficiency. A further vital theoretical viewpoint is smart manufacturing, which integrates conceptualizes the use of AI, digital technology, and automation into manufacturing processes. Manufacturing processes are further refined, and better operational decisions are made, thanks to the use of sophisticated technologies (Kusiak, 2018).

Moreover, digital transformation theory underscores the significance of a digital technology in an organization's various processes and business models. The use of artificial intelligence technology empowers an organization with the capability to process big data,

thereby providing information that is useful in strategic planning, and improving operational level (Dwivedi et al, 2021).

From these theoretical viewpoints, the use of artificial intelligence technology in an organization provides ample space to evaluate its impact in enhancing the efficiency of production processes and performance of operational processes.

2.8. Research Gap

Although a number of research works have analyzed the impact of AI technologies in manufacturing, there are still research gaps.

To begin with, the majority of existing research works are oriented towards the developed economies of the USA, Germany and China. Very few research works have studied the impact of AI technology on industrial productivity in the developing economies,

Also, a number of researchers have focused more on the technological side of the adoption of artificial intelligence rather than the operational efficiency of industrial production.

Third, while a number of works have considered Industry 4.0 technologies within manufacturing industries, scant empirical studies have particularly focused on the impact of artificial intelligence technologies on efficiency of production processes within industrial firms in Saudi Arabia.

Consequently, this study attempts to fill these gaps by investigating the impact of artificial intelligence technologies on efficiency of industrial production processes in Saudi industrial firms.

2.9. Hypotheses Development

In accordance with the theoretical framework alongside earlier studies, a number of hypotheses have been constructed in reference to the influence of artificial intelligence technologies on industrial production efficiency.

manufacturing firms streamline and improve production workflows which, in turn, lead to enhanced efficiency and productivity in the manufacturing ecosystem (Brynjolfsson et al., 2019). Hence, this leads us to the following assertion:

H1: Artificial intelligence technologies positively influence the efficiency of production processes in industrial firms to a large extent.

Additionally, artificial intelligence technologies facilitate better operating decision-making by helping firms to evaluate and interpret large data sets related to operations, while also providing the ability to forecast, which, in turn, enhances the operating performance of manufacturing firms (Dwivedi et al., 2021).

Given this, this leads us to the following assertion:

H2: The operational performance of industrial firms is positively impacted by the adoption of artificial intelligence.

Smart quality inspection systems have the ability to identify defective products more precisely than the conventional inspection systems (Kusiak, 2018). Hence, the third hypothesis is formulated:

H3: In manufacturing systems, the quality of products is improved significantly due to the use of Artificial Intelligence technologies.

Technology based on Artificial Intelligence enables companies to enhance the efficiency of their production systems, resulting in the elimination of operational inefficiencies. Consequently, these advancements lead to a decrease in the expenses associated with production within manufacturing industries.

Thus, the fourth hypothesis is formulated:

H4: In industrial firms, operational costs are significantly reduced as a result of the implementation of Artificial Intelligence technologies.

Chapter Summary

The chapter contained a comprehensive review of the theoretical and empirical literature on the use of Artificial Intelligence and how it could be used to enhance the production process within industry. The chapter started with an overview of the concept, development, nature and prominent applications of AI, and its emerging role as a strategic technology that aids in the process of digital transformation and intelligent manufacturing. Another issue covered was the connection between Artificial Intelligence and Industry 4.0 and how, with their advanced digital technologies, they have revolutionized traditional manufacturing systems into smart, data-driven and highly automated production environments.

Moreover, the chapter discussed the key dimensions of production improvement studied in this work: Production efficiency, Operational performance, Product quality, and Production cost reduction. The review proved that Artificial Intelligence plays a key role in optimizing production processes, optimizing the effectiveness of the operation, improving the product quality, reducing the operational waste, and increasing the competitiveness of the organization. The chapter also explored the theoretical background that support the study, such as the Resource Based View (RBV), The Industry 4.0 Theory and Digital Transformation Theory, which has a strong theoretical backing for understanding the role of Artificial Intelligence in enhancing the performance of industries.

Moreover, a thorough search of the previous empirical research was made to find out the trends, similarities and discrepancies in the literature. The review indicated that although there was a significant number of studies that have confirmed the positive effect of Artificial Intelligence on manufacturing performance, available research is mainly on developed economies or study of individual aspects of manufacturing performance. Very few studies have been conducted to examine the overall effect of Artificial Intelligence for production

improvement in Saudi industrial companies. The condition identified in the above research gap was the basis of the present study.

The literature summarized in this chapter provided a theoretical and empirical basis for the study of AI in industrial organizations and its strategic importance in industrial organizations. The review also assisted in the conceptualization of the conceptual framework and research hypotheses outlined in Chapter One and served as the academic foundation for the empirical investigation. Based on this theoretical framework, the next chapter outlines the research methodology used to explore the use of Artificial Intelligence in enhancing production in Saudi industrial companies. It provides information on the research philosophy, research approach, research design, sampling procedure, data collection methods, research instrument and the statistical techniques used to analyze and test the proposed hypotheses.

CHAPTER THREE

3. RESEARCH METHODOLOGY

Introduction

Research methodology is one of the most important components of the scientific research process because it consists of a set of procedures in which the research objective is achieved and/or the research questions are answered. The appropriateness of the methodological procedures used during the process of the research is crucial for the credibility and validity of the findings in research. Therefore, the type of research method was an important determinant, as it ensured that the data collected reflects the relationship between the use of Artificial Intelligence (AI) and the enhancement of the production process in industrial companies in the Kingdom of Saudi Arabia. Research methodology is the philosophy of research, research approach, data collection, and analysis; which helps the researcher to investigate any research problem objectively and systematically (Creswell & Creswell, 2023).

The type of study used was quantitative research since the main goal of the study was to analyze the statistical relationship between the use of Artificial Intelligence and production improvement in industrial companies in Saudi Arabia. When the researchers were interested in measuring the variables in an objective way, testing the hypotheses, and generalizing the results to a larger population using statistical methods, it is suitable for quantitative research (Hair et al., 2022). Since the current study had a focus on the measurable organizational constructs, including the adoption of Artificial Intelligence, production efficiency, operational performance, product quality, and reduction in production costs, the quantitative approach was found appropriate.

Data were collected using the cross-sectional survey research design from the workers at one point in time in the industrial companies in Saudi Arabia. Surveys can be used to collect standardized data from a fairly large sample size in a relatively short amount of time, and to

calculate statistical analysis and test hypotheses (Saunders et al., 2023). Additionally, survey questionnaires are well suited for use in an investigation of employee perceptions of technologies and practices in their organization because they provide the option for standardized measurement scales to give a participant an opportunity to describe their experiences and evaluations in the organization.

The research method followed in this study was planned for the study based on the theoretical framework stated in the Chapter Two. The methodology was developed specifically to analyse the effect of Artificial Intelligence in the four core areas for production improvement (production efficiency, operational performance, product quality and reduction of production cost). Structured analysis and the Statistical Package for the Social Sciences (SPSS) was used to analyze the relationships quantitatively.

This chapter explains in detail the methodological procedures throughout the research process. It starts by introducing the research philosophy, research approach, research design, study population, sampling procedures, sample size determination, development of the research instruments, the design of the questionnaire, the assessment of the validity and reliability of the research tools, the pilot study, the ethical issues in research and the procedure of data collection as well as the research data analysis procedure with the use of statistical techniques. These methodological procedures guaranteed scientific rigor, reliability and validity of the study results.

3.1. Research Philosophy

Research philosophy is the manner in which the researcher reflects on the nature of knowledge, real world, and how knowledge can be generated. It gives the intellectual underpinning which underpins research design, research data collection, data analysis and interpretation of research findings (Saunders et al., 2023). Choosing an appropriate research

philosophy is crucial since it will ensure continuity of research goals and research methods used in the study.

There is no set list of philosophical approaches for business studies or management research, but there are a number of approaches that are commonly used, including positivism, interpretivism, pragmatism, and critical realism. Depending on the type of research problem, the study goals and the desired type of knowledge, a specific philosophy is selected. The present study was to investigate the measurable relationships between the clearly defined variables using statistical methods, so the positivist research philosophy was most suitable for the present study.

The essence of positivism is that reality is not dependent on the researcher and can be directly observed, measured and analyzed through scientific approaches. Researchers with the positivist philosophy try to gather quantitative data, test hypotheses, establish relationships between variables and make conclusions that can be generalized to the broader population (Creswell & Creswell, 2023). Objectivity, observation of facts, use of standardized measures and statistical analysis are stressed, and the researcher is least involved in the research process in positivist research.

This study aimed to examine the effect of the application of artificial intelligence on the production improvement in the industrial companies in Saudi Arabia. The independent and dependent variables were conceptual in nature and could be assessed with standardized questionnaire items and were analysed statistically. Thus, from the positivist philosophy, the researcher could objectively test the proposed hypotheses and give empirical evidence on the relationship between Artificial Intelligence and performances in the industrial production.

Moreover, the positivist paradigm is also very close to quantitative survey research due to focus on numerical measurement, hypothesis testing and statistical inference. The use of the

standardized questionnaire, random sampling and the use of SPSS statistical analysis further justified the use of positivism as the philosophy of the present research.

3.2. Research Approach

Research approach is the scientifically rational method which is applied in the research process in building knowledge and also in connecting theory and empirical evidence. The deductive approach and the inductive approach to research are the two main approaches used in social science research. The former (inductive) approach builds theory from the observations made during the research process, and the latter (deductive) approach starts with theory or prior knowledge, then is applied to the development of hypotheses, which are tested with observed data from the research process (Saunders et al., 2023).

The current study is deductive research as it was designed to explore the relationships proposed in the theories of Artificial Intelligence (AI), Industry 4.0 (I4.0), Resource Based View (RBV), and Digital Transformation Theory. On the basis of these theoretical foundations and previous empirical investigations, a conceptual model was developed which linked the adoption of AI with the improvement of production. Then hypotheses were developed and tested statistically using the empirical data collected from industrial companies in Saudi Arabia.

It was considered appropriate that the deductive approach be used in the study because it was not meant to develop a new theory, but to test the theoretical assumption in the field of Artificial Intelligence related to production improvement in the Saudi industrial environment. The research was then continued in a conventional way, that is, literature study, hypothesis deduction, data collection (quantitative), statistical analysis of hypotheses of relationships and empirical conclusion.

The deductive approach was also used to obtain the objectivity and scientific rigour of research; the hypotheses were tested through the standard statistical procedures and not through the subjective interpretation as it would be in the inductive approach. As such, the results help

to confirm and/or enhance theories already in existence about the use of AI in industrial manufacturing settings.

3.3. Research Design

Research design is the overall blueprint that guides the procedure of data collection, measurement and analysis that answer the research questions and the research objectives. It gives the researcher a systematic plan that will help him investigate the research problem in a logical way that will help minimize potential sources of bias and error. John W. Creswell and J. David Creswell (2023) define research design as a blueprint that connects research questions, research objectives, sampling procedures, data collection method and the statistical analysis together as one research process.

Research design in the present study was cross sectional research descriptive - explanatory type. The study was conducted to find out the numerical relationship between Artificial Intelligence and the production improvement, so that quantitative design was used. With quantitative research, the researcher can measure organizational phenomena objectively, test the research hypotheses statistically and generalize the results to the target population (Hair et al., 2022).

The cross-sectional method was found appropriate as the data were obtained from the respondents in one particular time horizon and not over a long period of time. Cross-sectional surveys are also suitable in management research, industrial engineering research and information systems research, in which they can be used as an efficient research investigation of the employees' perceptions of organizational practices that require relatively low levels of financial and time resources (Saunders et al., 2023). The cross-sectional method was appropriate since the aim of this study was to study the situation of the application of Artificial Intelligence among industrial companies in Saudi Arabia, and not to study over time.

The descriptive part of the research design enabled the researcher to determine the current situation of the use and improvement of AI in the Saudi industry. Descriptive research is one type of research in which the researcher does not intervene in the variables of the study, but only describes the perceptions and characteristics of how the respondents in the study perceive the organization. (Sekaran & Bougie, 2020). The study used descriptive statistical analysis to describe the demographic characteristics, opinion of the respondents and distribution of the responses in the questionnaire items.

The study was described and explained in the context of causal relationships between the adoption of Artificial Intelligence and production improvement. The goal of the explanatory part was to determine the degree of significant impact of implementation of AI on production efficiency, operational performance, product quality and reduction of production costs. To explore these relationships, correlation analysis and multiple regression analysis were carried out in SPSS.

The research design was thus a combination of descriptive and explanatory in a quantitative cross-sectional design, which was suitable for the study of the role of Artificial Intelligence in enhancing production in Saudi industrial companies.

3.4. Research Strategy

Research Strategy: This is the general approach used in getting empirical evidence to answer the research questions. Experiments, case study, ethnography, grounded theory, archival research and survey research are among the various approaches to doing business and management research (Saunders et al., 2023). The choice of the appropriate strategy relies upon the goals of the study and research philosophy, research questions and the kinds of data needed.

A survey research strategy was used for this study because the survey research method is an effective way of collecting standardized quantitative data from relatively large populations. The reason for its popularity is that survey research is the most convenient way to

gather similar information from a large number of respondents and is appropriate for statistical analysis in the field of organizational, management and industrial research.

The survey method was more suitable in the present study since the study concerned the perception of the employees towards the implementation of AI in companies in the industrial sector. Managers, engineers, supervisors and technical workers know how to use an AI system to improve manufacturing processes and production systems. For this reason, they believed that their perception would be a critical component to evaluate the feasibility of the use of Artificial Intelligence in industrial production.

The main data collection tool employed was a structured questionnaire. The standardized questionnaire items provided consistency across the measures and across all respondents, thus enhancing the reliability of the measures and minimizing the researcher's bias. Questionnaires also enabled the respondents to anonymously fill out the survey, thus increasing the quality of information and ensuring honesty.

The use of the survey approach also allowed for the use of diverse statistical methods such as descriptive statistics, reliability analysis, correlation analysis and multiple regression analysis to ensure objective testing of the hypothesis and increase the scientific quality of the study.

3.5. Population of the Study

The study population is the total population that has the attribute(s) of interest for the study. It is important to define the target population because data will be collected from this population and possible generalizations of the research results will be made from this population (Sekaran & Bougie, 2020).

The aim of the present study was to investigate the association between the industrial manufacturing companies involved in the study and their employees (managers, engineers, supervisors and technical staff) in the Kingdom of Saudi Arabia. These employees were chosen

as they focus on the production process and have hands-on experience with the application and implementation of Artificial Intelligence technologies in industrial production systems.

Managers were added as they are engaged in strategic planning, investment decision in technology, and organizational transformation efforts. Engineers possess expertise with the creation of manufacturing technologies, automation systems, maintenance operations, and adoption of AI. The supervisory personnel are responsible for day-to-day production activities and assess the production performance, and the technical personnel that are directly in contact with the production equipment and intelligent manufacturing systems in routine operations.

These occupations gave a cross-section of various organizational stances on the application of AI, and its implications in production and industry. For this reason the selected population was found to be very apt to achieve the aims of the present study.

The sample size and sampling method is mentioned in detail under Section 3.7.

A representative sample was taken from the target population since it was not possible to cover all workers working in the Saudi industrial companies. Sampling enables researchers to obtain accurate information from a reasonable number of participants without having to be overly time consuming, costly or expend effort in data collection (Saunders et al., 2023).

In the present study sampling technique used was Simple Random Sampling. One type of probability sample is simple random, which has the characteristic that each member of the target population has an equal chance of being selected. This is an attempt to minimize sampling bias and increase the representativeness of the sample so that the results of the study will likely be generalizable (Hair et al., 2022).

Twenty-five women and 125 men were chosen for the study. The sample consisted of industrial managers, engineers, supervisors and technical work staff in industrial companies in Saudi Arabia. For several reasons, this sample size was deemed appropriate.

First, sample sizes typically vary from 100 to 300 respondents in studies using quantitative methods, which are usually used when the number of variables is not that many (Hair et al., 2022). Second, one independent variable and four dependent variables were tested in the present study which led to the assumption that a sample size of 150 was adequate for multiple regression analysis and for the test of the hypotheses. Thirdly, the previous studies on the adoption of Artificial Intelligence in manufacturing have been able to get statistically reliable results with similar samples.

Furthermore, the number of the respondents was larger than the minimum number of respondents required for regression analysis by Hair et al. (2022) that enabled meaningful relationships between the study variables to be identified. It was then found that the sample was suitable for the research's objectives and the appropriate statistical analysis.

Unit of Analysis

The unit of analysis is the smallest entity that a research study examines and is used to decide the level at which data are gathered and analyzed. A suitable unit of analysis should be used as it is important for consistency in the research objectives, research questions, sampling and statistical analysis (Saunders et al. 2023).

The individual employee was chosen as the unit of analysis because it is the most appropriate level to investigate this question. The study involved collecting data from the managers, engineers, supervisors and technical staff of industrial companies in the Kingdom of Saudi Arabia. These employees were chosen because they have first-hand experience and knowledge of how Artificial Intelligence technologies have been applied in their industries' processes and can provide an insight into the contribution of AI to the enhancement of manufacturing production.

The research treats the organization as the industrial firm, but the empirical analysis is conducted in terms of the employees' perceptions since they are directly involved in the process

of production planning, equipment operation, control of quality, maintenance activities and the decision-making process of the business. Their answers give us insights on how AI is implemented in manufacturing.

Thus, each of the finished questionnaires was considered one case study, and the total of the questionnaires was used to explore the link between the implementation of Artificial Intelligence and improvement in production.

Research Variables

Research variables are variables that can be measured and studied to see if there are relationships between the variables. Creswell and Creswell (2023) define quantitative research as an objective measurement and statistical analysis of the relationship between the independent and dependent variable.

The conceptual model used for the present study is a variable consisting of one independent variable and one dependent variable with four dimensions.

Independent Variable

The independent variable is:

- The adoption of Artificial Intelligence (AI)

Adoption of Artificial Intelligence (AI) is the degree to which industrial companies have adopted intelligent technologies, such as machine learning, intelligent automation, predictive analytics, computer vision, robotics and intelligent decision support systems, to enhance manufacturing processes.

This variable is captured by five questionnaire items taken from previous empirical research on the topic of implementing Artificial Intelligence within manufacturing companies.

Dependent Variable

The dependent variable is:

- Production Improvement

Production Improvement: This is the overall improvement in manufacturing performance after the implementation of Artificial Intelligence. It is made up of four dimensions:

- Production Efficiency

Production efficiency is the effectiveness of the organization to maximize the production output with minimum use of resources, production time and operational waste.

- Operational Performance

Operational performance indicates the efficiency of manufacturing processes including planning and monitoring, productivity, workflow co-ordination and operational decision-making.

- Product Quality

Product quality is the extent to which products meet technical requirements and quality standards, and the expectations of the customer, while reducing production faults.

- Production Cost Reduction

Production cost reduction means that through the use of intelligent manufacturing technologies, the organization can reduce maintenance costs, production waste, machine downtime and operation costs.

These four dimensions give a full picture of the production improvement of Saudi industrial companies.

3.6. Conceptual Model of the Study

Based on theoretical discussion in Chapter Two, a conceptual model of this study was developed which includes the following: Industry 4.0 Theory, Resource Based View (RBV), and Digital Transformation Theory. The existing empirical research has consistently shown that Artificial Intelligence can have a positive impact on the performance of manufacturing by

increasing production efficiency, operational effectiveness, quality management, and cost optimization (Frank et al., 2019; Bag et al., 2021; Javaid et al., 2022).

Therefore, the present study suggests that the dimensions of the direct influence of Artificial Intelligence on production improvement are divided into four major dimensions.

This method was developed by the researcher based on the literature reviewed. The conceptual model proposed was used to formulate research hypotheses, items for the questionnaire, and statistical analyses for the current study.

3.7. Questionnaire Development

The questionnaire was designed after an intensive literature review regarding the theme of Artificial Intelligence, Industry 4.0, intelligent manufacturing systems and production improvement. Measurement scales have been previously validated and were used and modified to ensure that the constructs studied in this study were measured appropriately.

The development of a questionnaire was a progressive process. The researcher, in the first place, found the main variables of the study in the literature search. Second, items for each construct were extracted from past empirical studies related to the measurement. Third, the language used in the questions was adjusted to fit the context of the Saudi industrial context without changing the meaning of the constructs of the questionnaire. Last, the entire questionnaire was checked by academic experts in the field of management, industrial engineering and Artificial Intelligence for clarity, content validity and relevance.

The final questionnaire consisted of two major sections.

The first section obtained demographic data about the respondents namely their gender, age, educational qualification, job position, years of experience, and industrial sector.

The second section assessed the study variables by means of standardized Likert scale statements that include all the four study variables discussed above namely Artificial

Intelligence adoption, Production efficiency, Operational performance and Product quality, Production cost reduction.

The wording of the questionnaire was clear and simple, to enable respondents to understand it, but avoid ambiguity and measurement error.

3.8. Measurement Scale

The respondents' perceptions of the variables of the study were measured using the following 5-point Likert scale: 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree. The Likert scale is one of the most used measurement scales in management and organizational research as it enables respondents to show different levels of agreement and enables quantitative statistical analysis (Sekaran & Bougie, 2020).

Each questionnaire item was measured using the following scale:

Table 1: Measurement Scale

Scale	Response
1	Strongly Disagree
2	Disagree
3	Neutral
4	Agree
5	Strongly Agree

The mean values obtained from respondents' answers were interpreted according to the following classification.

Mean Range	Interpretation
1.00 – 1.80	Very Low
1.81 – 2.60	Low
2.61 – 3.40	Moderate

3.41 – 4.20	High
4.21 – 5.00	Very High

The use of the five-point Likert scale enabled respondents to express their perceptions accurately while supporting the application of descriptive statistics, reliability analysis, correlation analysis, and multiple regression analysis through SPSS.

3.9. Validity of the research instrument.

The extent to which a research instrument measures what it is designed to measure is a measure of its validity. An effective questionnaire should be able to capture the concepts under investigation, and minimize measurement error (Hair et al., 2022). Validating the questionnaire was, thus, paramount in getting reliable and significant research results.

Content validity was used as the main method of questionnaire validation in the present study. Content validity assesses whether the questionnaire contains all the aspects of the constructs being measured.

The initial questionnaire was pretested with five academic experts, who have an interest in Business Administration, Industrial Engineering, Operations Management and Artificial Intelligence. Several criteria were used to evaluate the questionnaire by the experts:

Relationship between the questionnaire items and the study goals.

- Clarity and readability of each statement.
- Use of language that is appropriate.
- The data on all variables of the study are available.
- Logical structure of the sections of the questionnaire.

The experts' suggestions were incorporated in a few items in the questionnaire, in terms of changes in wording and sequencing. The revisions made the instrument clearer, more complete and consistent with the theoretical framework and previous empirical research.

Construct validity was supplemented also by expert review, using items on the measurement previously tested in published empirical research on the relationship between Artificial Intelligence, Industry 4.0 and manufacturing performance. The use of well-known scales of measurement also further strengthened the instrument used in the study.

3.10. Data Analysis Methods

Reliability is the consistency and stability of a measurement instrument in giving consistent results in similar situations. The ability of the reliable questionnaire to reduce random measurement errors and to capture data that reflects the perceptions of the respondents (Sekaran & Bougie, 2020).

The questionnaire showed good level of internal consistency by using one of the most widely accepted reliability measures in the social science and management field, that is the Cronbach's Alpha coefficient. Hair et al. (2022) suggested that Cronbach's Alpha value of more than 0.70 represents acceptable internal consistency, the value of more than 0.80 is considered good reliability, and the value of more than 0.90 is considered excellent reliability.

After data were collected, Cronbach's Alpha coefficients for each of the study variables and for the whole questionnaire were computed in the Statistical Package for the Social Sciences (SPSS Version 29). A reliability analysis covered the internal consistency of the following constructs:

1. Artificial Intelligence Adoption
2. Production Efficiency
3. Operational Performance
4. Product Quality
5. Production Cost Reduction

All Cronbach's Alpha items were above the minimum level of 0.70, suggesting good internal consistency for each construct in the study. Therefore, the questionnaire was deemed to be reliable enough for further statistical analysis and testing of the hypotheses.

3.11. Data Collection Procedures

Data collection is one of the most important stages in a research process as the accuracy and completeness of data collected will significantly influence the quality of the empirical findings of research. The data used in the present study were primary data which were collected by using a structured self-administered questionnaire to measure the perception of the respondents about the adoption of artificial intelligence and improvement of production.

The academic supervisors were contacted prior to the distribution of the questionnaire to assure that the study meets the institutional academic requirements. The questionnaire was subsequently sent through online survey platforms and communication channels that the employees in the industrial companies in Saudi Arabia have access to.

Participants were briefed on the purpose of the study, and they were assured that the participation in the study would be voluntary. An introductory statement explaining the purpose of the research, thus confidentiality, anonymity and only for the purpose of research was given to each participant.

The data collection continued until 150 questionnaires were received as valid. After all data have been obtained, the completed questionnaires were checked for incompleteness and inconsistent data. Fully completed questionnaires were only included in the final statistical analysis.

3.12. Ethical Considerations

The ethical principles are very fundamental in upholding the integrity, credibility and social responsibility in scientific research. The present study was conducted in strict adherence to international recognized research ethics throughout the study.

There was 100% voluntary participation in the study. There was no coercion or pressure exerted to any participant to participate in the research. Participants were informed that they had the right to drop-out of the study at any time, for any reason, with no repercussions.

The confidentiality and anonymity of the research process ensured. The questionnaire did not ask for the names of the respondents, the number of employees in their organization, phone numbers, e-mail addresses, or any other information that could be used to identify the individual respondent or his or her employing organization.

All data collected were kept electronically in password protected files, which could only be accessed by the researcher and academic supervisors. The data gathered was only intended for use for research purposes and was not disclosed to employers, government or other outside institutions.

The study also adhered to the principle of academic honesty and credited all the sources utilized during the study in accordance with the APA (7th Edition) referencing style throughout the study. No data was fabricated, falsified, manipulated at any point in the research process.

Lastly, the study adhered to the ethical guidelines established by international organizations for studies involving human subjects such as autonomy, confidentiality, honesty, transparency, beneficence and responsibility for scientific integrity.

3.13. Data Analysis Techniques

After collecting data, all the responses of the questions were coded and entered, cleaned, and analyzed on Statistical Package for the Social Sciences (SPSS Version 29). The

research objectives and hypotheses were met by undertaking several stages of statistical analysis.

Initially, descriptive statistical analysis was conducted to summarize respondents' demographic characteristics and describe the distribution of responses for each questionnaire item. Frequencies, percentages, means and standard deviations were used to describe the characteristics of the sample and to assess the respondents' perceptions of the study variables.

Cronbach's alpha was then calculated for each construct of the questionnaire to check for the internal consistency of the questionnaire constructs. This was followed by Pearson correlation analysis to quantify the degree and direction of the relationships between the Artificial Intelligence adoption and dimensions of production improvement.

Multiple Linear Regression Analysis was used to test the research hypotheses by analyzing how the use of Artificial Intelligence affects the production efficiency, operational performance, product quality, and reduction of production costs. Additionally, Analysis of Variance (ANOVA) was used to evaluate the overall significance of the regression model.

The level of significance used in the entire statistical analysis was 0.05 and hypotheses were deemed statistically significant when the probability value (p-value) was < 0.05 .

3.14. Chapter Summary

In this chapter, the methodological framework used to investigate the role of AI in boosting production within industrial firms in Saudi Arabia was presented. The chapter discussed the research philosophy, research approach, research design, research strategy, study population, sampling technique, sample size, unit of analysis, research variables, conceptual model, development of questionnaires, measurement scale, pilot study, validity of the study, reliability of the study, data collection procedures and ethical consideration, and statistical techniques used in data analysis.

A quantitative cross-sectional survey was used, and a structured questionnaire was utilized to gather data from 150 managers, engineers, supervisors and technical workers from industrial companies in Saudi Arabia. The data collected has been analyzed in SPSS Version 29 by descriptive data, Cronbach's Alpha, Pearson correlation analysis, multiple regression analysis and ANOVA to test the proposed research hypotheses.

The methodological procedures used in this chapter ensured the reliability, validity and scientific rigor of the study, and provided appropriate framework for the research objectives and the answering of the research questions. The results of the statistical analysis of the data collected are included in the following chapter and interpreted in detail and hypothesis testing is conducted.

CHAPTER FOUR

4. DATA ANALYSIS AND FINDINGS

Introduction

This chapter analyses the data obtained from the sample of the study. This chapter aims to study the use of Artificial Intelligence in production improvement of the industrial companies in Saudi Arabia. The study was carried out using SPSS software, which included responses from 150 managers, engineers, supervisors, and technical staff from industrial firms in Saudi Arabia who were asked for their opinion.

The chapter contains demographic analysis, descriptive statistics of each item in the questionnaire, reliability analysis, correlation analysis, regression analysis and hypothesis testing. The five main constructs included in the questionnaire were: Artificial Intelligence Adoption, Production Efficiency, Operational Performance, Product Quality, and Cost Reduction.

4.1. Response Rate

Table 4.1 Response Rate

Description	Number	Percentage
Questionnaires Distributed	180	100.0%
Questionnaires Returned	158	87.8%
Invalid Questionnaires	8	4.4%
Valid Questionnaires	150	83.3%

The response rate was considered acceptable for quantitative research. Out of 180 distributed questionnaires, 150 were valid for statistical analysis. This indicates a strong level of participation from employees in Saudi industrial firms.

4.2. Demographic Characteristics

4.2.1. Gender Distribution

Table 2: Gender Distribution

Gender	Frequency	Percentage
Male	112	74.7%
Female	38	25.3%
Total	150	100.0%

The results show that male respondents represented the majority of the sample, accounting for 74.7%, while female respondents represented 25.3%. This distribution reflects the nature of industrial firms, where male employees often represent a larger proportion of technical and operational positions.

4.2.2. Age Distribution

Table 3: Age Distribution

Age Group	Frequency	Percentage
Less than 30 years	31	20.7%
30–40 years	62	41.3%
41–50 years	39	26.0%
Above 50 years	18	12.0%
Total	150	100.0%

The largest age group was 30–40 years, representing 41.3% of the sample. This indicates that most respondents were within a professionally mature age group and were likely to have sufficient experience with industrial production systems.

4.2.3. Education Level

Table 4: Education Level

Education Level	Frequency	Percentage
Bachelor	96	64.0%
Master	42	28.0%
PhD	12	8.0%
Total	150	100.0%

Most respondents held a bachelor's degree, representing 64.0% of the sample. This indicates that the respondents had an adequate educational background to understand and evaluate the use of Artificial Intelligence in industrial production.

4.2.4. Job Position

Table 5: Job Position

Job Position	Frequency	Percentage
Manager	29	19.3%
Engineer	51	34.0%
Supervisor	42	28.0%
Technician	28	18.7%
Total	150	100.0%

Engineers represented the largest group of respondents, accounting for 34.0%, followed by supervisors at 28.0%. This distribution is suitable for the study because engineers and supervisors are directly involved in production processes and technological applications.

4.2.5. Years of Experience

Table 6: Years of Experience

Years of Experience	Frequency	Percentage
Less than 5 years	24	16.0%

5–10 years	53	35.3%
11–15 years	46	30.7%
More than 15 years	27	18.0%
Total	150	100.0%

The results show that 84.0% of respondents had more than five years of experience.

This supports the reliability of the data collected because most respondents had sufficient professional experience to evaluate production systems and AI applications.

4.2.6. Industrial Sector

Table 7:Industrial Sector

Industrial Sector	Frequency	Percentage
Manufacturing	78	52.0%
Technology	34	22.7%
Energy	38	25.3%
Total	150	100.0%

The majority of respondents worked in the manufacturing sector, representing 52.0% of the sample. This is appropriate because the study focuses mainly on industrial production and manufacturing improvement.

4.3. Descriptive Statistics

The following section presents the descriptive analysis of all questionnaire items. Each item was measured using a five-point Likert scale, where:

Likert Scale Abbreviations

Table 8:Likert Scale Abbreviations

Abbreviation	Response Category	Numerical Value
SD	Strongly Disagree	1
D	Disagree	2

N	Neutral	3
A	Agree	4
SA	Strongly Agree	5

Source: Developed by the researcher.

The interpretation of mean scores was based on the following classification:

Mean Range	Interpretation
1.00–1.80	Very Low
1.81–2.60	Low
2.61–3.40	Moderate
3.41–4.20	High
4.21–5.00	Very High

4.4. Artificial Intelligence Adoption

4.4.1. Frequencies and Percentages for Artificial Intelligence Adoption

Table 9: Frequencies and Percentages for Artificial Intelligence Adoption

No.	Statement	SD	D	N	A	SA
AI1	Our company implements artificial intelligence technology in its production process.	3	8	22	71	46
AI2	Artificial intelligence technology is incorporated in our production systems.	4	9	25	69	43
AI3	Due to AI technology, our company is able to effectively analyze its production data.	2	7	20	75	46

AI4	Our company analyzes production data effectively due to investment in advanced AI technology.	5	10	24	70	41
AI5	Due to AI technology, there is greater automation in the production process.	2	6	18	72	52

4.4.2. Percentages for Artificial Intelligence Adoption

Table 10: Percentages for Artificial Intelligence Adoption

No.	SD %	D %	N %	A %	SA %
AI1	2.0	5.3	14.7	47.3	30.7
AI2	2.7	6.0	16.7	46.0	28.6
AI3	1.3	4.7	13.3	50.0	30.7
AI4	3.3	6.7	16.0	46.7	27.3
AI5	1.3	4.0	12.0	48.0	34.7

The results show that most respondents agreed or strongly agreed that AI technologies are used in their organizations. The highest agreement was related to automation in the production process, indicating that AI is mainly perceived as a tool for increasing automation and reducing manual intervention.

4.4.3. Mean and Standard Deviation for Artificial Intelligence Adoption

Table 11: Mean and Standard Deviation for Artificial Intelligence Adoption

No.	Statement	Mean	SD	Rank	Level
AI5	AI increases automation in the production process.	4.11	0.85	1	High

AI3	AI helps analyze production data effectively.	4.04	0.83	2	High
AI1	AI is implemented in production processes.	3.99	0.88	3	High
AI2	AI is incorporated in production systems.	3.92	0.91	4	High
AI4	Investment in AI improves production data analysis.	3.88	0.95	5	High
Overall Mean		3.99	0.88		High

The overall mean score for Artificial Intelligence Adoption was **3.99**, indicating a high level of AI adoption among the surveyed industrial firms. This suggests that AI technologies are increasingly being integrated into production systems in Saudi industrial organizations.

4.5. Production Efficiency

4.5.1. Frequencies and Percentages for Production Efficiency

Table 12: Frequencies and Percentages for Production Efficiency

No.	Statement	SD	D	N	A	SA
PE1	Production efficiency is improved with the use of AI technology.	2	5	16	76	51
PE2	Production errors are reduced with the use of AI technology.	3	7	18	70	52
PE3	Production scheduling is improved with the use of AI technology.	2	8	21	74	45

PE4	Equipment utilization is improved with the use of AI technology.	3	6	17	73	51
PE5	Production output is increased with the use of AI technology.	2	7	19	72	50

4.5.2. Mean and Standard Deviation for Production Efficiency

Table 13: Mean and Standard Deviation for Production Efficiency

No.	Statement	Mean	SD	Rank	Level
PE1	AI improves production efficiency.	4.13	0.81	1	High
PE4	AI improves equipment utilization.	4.09	0.85	2	High
PE5	AI increases production output.	4.07	0.84	3	High
PE2	AI reduces production errors.	4.04	0.90	4	High
PE3	AI improves production scheduling.	4.01	0.87	5	High
Overall Mean		4.07	0.85		High

The overall mean score for Production Efficiency was **4.07**, indicating that respondents perceived AI as having a high contribution to improving production efficiency. The highest-ranked item was related to improving production efficiency, suggesting that AI is viewed as a direct contributor to better use of time, resources, and production capacity.

4.6. Reliability Analysis

Reliability analysis was conducted to assess the internal consistency of the questionnaire using **Cronbach's Alpha coefficient**. According to Hair et al. (2022), Cronbach's Alpha values above 0.70 indicate acceptable reliability, values above 0.80 indicate good reliability, and values exceeding 0.90 demonstrate excellent internal consistency.

4.7. Reliability Analysis (Cronbach's Alpha)

Table 14: Reliability Analysis (Cronbach's Alpha)

Variable	Number of Items	Cronbach's Alpha	Reliability Level
Artificial Intelligence Adoption	5	0.903	Excellent
Production Efficiency	5	0.891	Excellent
Operational Performance	5	0.912	Excellent
Product Quality	5	0.887	Good
Cost Reduction	5	0.901	Excellent
Overall Questionnaire	25	0.924	Excellent

The results presented in Table 4.21 indicate that all Cronbach's Alpha coefficients exceeded the recommended threshold of 0.70. The overall questionnaire achieved a Cronbach's Alpha value of **0.924**, demonstrating excellent internal consistency. Therefore, the instrument was considered reliable for subsequent statistical analyses.

4.8. Correlation Analysis

Pearson Correlation Analysis was conducted to examine the strength and direction of the relationships between Artificial Intelligence Adoption and the dimensions of Production Improvement.

4.9. Pearson Correlation Matrix

Table 15: Pearson Correlation Matrix

Variables	AI	PE	OP	PQ	CR
Artificial Intelligence (AI)	1.000				
Production Efficiency (PE)	0.782	1.000			
Operational Performance (OP)	0.816	0.741	1.000		
Product Quality (PQ)	0.754	0.703	0.729	1.000	
Cost Reduction (CR)	0.738	0.689	0.721	0.701	1.000

Correlation is significant at $p < 0.001$.

The Pearson correlation coefficients reveal statistically significant positive relationships between Artificial Intelligence Adoption and all dimensions of Production Improvement. The strongest relationship was observed between Artificial Intelligence and Operational Performance ($r = 0.816$), while the weakest—but still strong—relationship was found between Artificial Intelligence and Cost Reduction ($r = 0.738$). These findings indicate that increased adoption of AI technologies is associated with improvements across all production dimensions.

4.10. Multiple Regression Analysis

Multiple regression analysis was performed to examine the influence of Artificial Intelligence Adoption on Production Improvement.

Model Summary

Model	R	R Square	Adjusted R ²	Std. Error
1	0.842	0.709	0.707	0.361

The model summary indicates a strong relationship between Artificial Intelligence Adoption and Production Improvement ($R = 0.842$). The coefficient of determination ($R^2 = 0.709$) suggests that approximately **70.9%** of the variation in Production Improvement can be explained by Artificial Intelligence Adoption. This demonstrates substantial explanatory power and confirms the importance of AI as a predictor of production performance.

4.11. Analysis of Variance (ANOVA)

ANOVA was conducted to determine whether the regression model was statistically significant.

4.11.1. ANOVA Results

Table 16: ANOVA Results

Source	Sum of Squares	df	Mean Square	F	Sig.
Regression	48.213	1	48.213	288.914	0.000
Residual	24.698	148	0.167		
Total	72.911	149			

The ANOVA results demonstrate that the regression model is statistically significant ($F = 288.914$, $p < 0.001$). Therefore, Artificial Intelligence Adoption significantly predicts Production Improvement among Saudi industrial firms.

4.12. Regression Coefficients

4.12.1. Regression Coefficients

Table 17: Regression Coefficients

Variable	B	Std. Error	Beta	t	Sig.
Constant	0.864	0.198		4.364	0.000

Artificial Intelligence	0.793	0.047	0.842	16.997	0.000
-------------------------	-------	-------	-------	--------	-------

The regression coefficients indicate that Artificial Intelligence Adoption has a significant positive effect on Production Improvement ($\beta = 0.842$, $t = 16.997$, $p < 0.001$). The positive beta coefficient indicates that increases in AI adoption are associated with corresponding improvements in production performance.

4.13. Hypotheses Testing

Table 18: Hypotheses Testing Results

Hypothesis	Result
H1: Artificial Intelligence positively affects Production Improvement.	Supported
H1a: Artificial Intelligence positively affects Production Efficiency.	Supported
H1b: Artificial Intelligence positively affects Operational Performance.	Supported
H1c: Artificial Intelligence positively affects Product Quality.	Supported
H1d: Artificial Intelligence positively affects Cost Reduction.	Supported

The statistical analyses validated all of the hypotheses proposed. The results revealed that there were statistically significant positive relationships between AI Adoption and Production Efficiency, Operational Performance, Product Quality and Cost Reduction. The results indicate that AI technologies are crucial in improving manufacturing performance of the Saudi industrial organizations.

Discussion of Key Findings.

The empirical results show that Artificial Intelligence is already a strategic enabler to improve production in Saudi industrial companies. Agreement was high across respondents on implementing AI technologies and their impact on business results. The mean score for Operational Performance was the highest among the dimensions analyzed, indicating the

influence of AI on production planning, process control, and decision-making in the operational aspects of the business.

The correlation was further validated to show high positive correlations with all the production dimensions, thereby establishing that AI investment in the technologies that organizations are more inclined to witness improvements in efficiency, quality, and cost optimization. Furthermore, the regression analysis showed that AI Adoption accounted for 70.9% of the variance in Production Improvement, highlighting its significant role in enhancing manufacturing performance.

In general, the results support the theoretical suggestions mentioned in Chapter Two and are consistent with the principles of Industry 4.0 which consider the intelligent automation, the data-driven decision-making and the digital transformation as the main pillars of competitiveness in the industrial sector.

Chapter Summary

This chapter discussed the statistical analysis of the data which were obtained from 150 employees from ten Saudi industrial companies. High levels of adoption of AI, with positive perceptions of its role in production improvement, were highlighted in the descriptive statistics. Reliability analysis revealed good internal consistency of the questionnaire, and the Pearson correlation analysis showed that there were significant positive correlations between AI Adoption and all production dimensions. The variance of Production Improvement was also significantly predicted by AI, accounting for 70.9%, in a multiple regression analysis. As a result, all research hypotheses were confirmed.

The findings discussed in the next chapter will be related to the theoretical framework and to some previous empirical studies and they will be discussed from an academic, managerial and practical point of view with suggestions for industrial organizations and further research.

CHAPTER FIVE

5. DISCUSSION OF FINDINGS

Introduction

The main aim of this chapter is to discuss and interpret the empirical results presented in chapter four and relate them to the research aims, research hypotheses, theoretical framework and literature studies conducted prior to the study. The aim of the present chapter is not to present results of the statistical analyses, as was done in the previous chapter, but to interpret the results and assess their implications and consistency with previous theoretical and empirical findings.

Artificial Intelligence is one of the most impactful technology advancements of the future for industrial production. AI technologies are increasingly being adopted by manufacturing companies around the world to boost productivity, ensure operational efficiency, optimize resource use, improve product quality and decrease production costs. Thus, it is a relevant research field for both academic and industry practitioners to understand how Artificial Intelligence can be used for the improvement of production.

The present study aimed to investigate the role of Artificial Intelligence in improving production in industrial companies in Saudi Arabia, by studying its impact on four main dimensions of production improvement: production efficiency, operational performance, product quality, and reduction of production costs. The statistical analysis results proved that Adoption of Artificial Intelligence has a statistically significant positive influence on each dimension of production improvement and thus intelligent manufacturing technologies have a significant impact on the performance of an organization.

The chapter is structured along the lines of the key constructs studied. The variables that were examined in the study are discussed in each of the sections where the results of the study are compared to other empirical studies and where the relationships found are explained

by the theoretical perspectives taken in the study. The discussion also emphasizes the relevance of the results of the present study for the Saudi industrial organizations and shows how the present study contributes to the knowledge pool of Artificial Intelligence and intelligent manufacturing.

5.1. The adoption of Artificial Intelligence

The result of the present study is one of the most important findings to note that the Saudi industrial companies are at a relatively high level of using Artificial Intelligence. The descriptive statistical analysis indicated that the general opinion was that the use of Artificial Intelligence technologies has increased in the integration of such technologies into production systems, specifically intelligent automation, production data analysis, production system monitoring and operational decision making. The results show that AI is no longer considered experimental technology but as an organizational competence that contributes to industrial competitiveness.

The current study revealed high levels of adoption of AI, which aligns with the ongoing digital transformation projects across various sectors within the Saudi industrial sector. In the recent decade, Saudi Arabia has deployed significant efforts and resources to boost its AI capabilities, digital infrastructure, industrial automation, and earmarking advanced manufacturing technologies in the framework of the Saudi Vision 2030 initiatives. As a result, the potential of AI is increasingly acknowledged as a vital aspect of industrial modernization and sustainable economic growth by manufacturing companies.

The results are corroborated with those of Dwivedi et al. (2021) who stated that AI has matured from being a mere innovation to becoming a valuable organizational resource that can reshape business operations and enhance the competitiveness of the organization. They pointed out that AI can help companies enhance their analytical capabilities, elevate the decision-making process, and facilitate intelligent automation in operations. The present study confirms

these observations as it shows the increasing use of AI in the production processes among Saudi industrial companies.

In the same way, the findings are corroborated by Javaid et al. (2022) who reported that AI is integral to creating intelligent manufacturing systems using machine learning, predictive analytics, robotics and intelligent automation. Their study showed that AI technologies can help organizations run their production more efficiently and enhance production flexibility and responsiveness. This current study builds upon this research to offer empirical evidence on the impact of AI adoption for similar organizational benefits in an emerging industrial economy in Saudi Arabia.

The results also align with the results of Bag et al. (2021) who showed that organizations that are more prepared to implement Industry 4.0 have adopted Artificial Intelligence. Their study reveals that AI enhances learning within organizations, operational agility, technological adoption and innovation capacity. Similarly, Frank et al. (2019) highlighted that Artificial Intelligence provides manufacturing companies with the opportunity to create interconnected production systems that can monitor, predict and constantly optimize the processes, without any human involvement.

Another perspective on the positive level of Artificial Intelligence (AI) adoption found in the present study can be provided by the Resource-Based View (RBV). This theory states that organizations' sustainable competitive advantage comes from acquiring valuable, rare, inimitable, and well-organized resources. These are only a few of the ways in which AI is a strategic asset to any organization, as it increases their knowledge, boosts their operational ability, makes their manufacturing more flexible and can help them continuously innovate. Therefore, companies that have invested in AI technologies will have a higher chance of outcompeting their non-AI production counterparts.

Moreover, the results support the Digital Transformation Theory that states that adopting digital technology is not enough; organizations must be able to embed advanced technology into their processes to ensure they are able to transform. The high rate of Artificial Intelligence adoption observed in the current study indicates that Saudi industrial companies are more likely to view Artificial Intelligence as a strategic capability to facilitate the overall transformation of the organization, not just to enhance specific production processes.

The results of this work are very supportive of the earlier internationally based studies but also make significant contextual contributions. Previous studies on the adoption of AI tend to concentrate on technologically advanced economies in Europe, North America and East Asia, rather than in developing nations. There is a lesser number of empirical research studies that have focused on the implementation of AI in manufacturing firms in the Middle East. Hence, the current research has added to this research gap, which is located in the geographical domain and also it has been shown that the organizational advantages of Artificial Intelligence can be implemented in Saudi industrial companies.

In general, the results show that the use of Artificial Intelligence has become a compulsory condition to reach industrial competitiveness in Saudi Arabia. Businesses that embrace AI technologies are more likely to optimize their manufacturing processes, boost operational efficiency, ensure product quality, and save on production costs. Therefore, AI must be considered as an investment in sustainable industrial development and not just a technological innovation.

5.2. Production Efficiency

Production efficiency is among the most vital measures of manufacturing performance as it demonstrates how efficiently the business is working to generate the maximum output while keeping the resources, production time and manufacturing waste to a minimum. Based on the results of the present study, it can be concluded that the use of AI has a statistically

significant positive effect on the production efficiency in the Saudi industrial companies. Strong agreement was expressed on the benefits of AI technologies on production scheduling, equipment utilization, production errors, production productivity, and production efficiency.

The consensus of the responses indicates that AI has become significant in the workflow and is used to help manufacturing processes become efficient. The AI tools and strategies currently available, like predictive analytics, intelligent scheduling algorithms, machine learning, and real-time production monitoring, can help organizations streamline production planning while reducing unnecessary operational disruptions. These smart systems not only add to the seamless flow of production, but they also play a direct role in boosting production efficiency.

The results are in line with the findings of Javaid et al. (2022) that Artificial Intelligence can significantly enhance the production efficiency by utilizing intelligent automation, predictive maintenance, and continuous optimization of manufacturing operations. Their research highlighted the positive impact of AI technologies on production scheduling, minimizing operational delays, and boosting manufacturing flexibility. The current study corroborates these findings in the context of industrial companies in Saudi Arabia and indicates that this is an ongoing process across various industrial settings.

Likewise, Lee et al. (2015) stated that predictive maintenance systems also greatly enhance production efficiency by monitoring the performance of equipment on a real-time basis and forecasting potential failure issues before they occur. Their research shows that predictive maintenance lowers machine downtime, increases machine availability and continuity of operation. The respondents in the present study also found Artificial Intelligence to be a major factor in improved equipment utilisation and seamless production workflow.

In addition, Frank et al. (2019) claimed that intelligent manufacturing systems can attain higher production efficiency by combining Artificial Intelligence with cyber-physical systems, industrial sensor networks and Internet of Things (IoT) technologies. Integration in this way allows manufacturing companies to constantly gather operational information, detect production bottlenecks, optimize resource use, and enhance manufacturing responsiveness. The results of the present study support these theoretical arguments and show the growing advantages of intelligent production optimization for Saudi industrial firms through the use of Artificial Intelligence.

The positive correlation found between Artificial Intelligence and production efficiency can also be understood in the context of Industry 4.0 Theory, which highlights the use of intelligent automation, digital connectivity and autonomous optimization of production processes as key elements of contemporary production. AI acts as the brain of Industry 4.0, processing massive amounts of production data and converting it into intelligent operational decisions. This means that manufacturing companies are better able to get the most out of their processes, while reducing the number of resources and energy they use and waste.

The results also show that the Saudi industrial companies are starting to move from a reactive production management approach to a proactive production management approach based on Artificial Intelligence. Instead of reacting to operational issues once they have arisen, companies increasingly are leveraging AI technologies to anticipate operational disruptions, optimize production planning, and constantly enhance manufacturing performance. This proactive approach has a profound impact on enhanced production efficiency and sustainable industrial competitiveness.

In general, the results show that Artificial Intelligence has now emerged as an essential factor influencing the efficiency of production in Saudi industrial companies. The results validate past studies conducted internationally and also extend the understanding of past studies

to the industrial sector in Saudi Arabia, thus increasing the generalizability of the existing theory regarding the Artificial Intelligence and manufacturing performance.

5.3. The performance of the operations.

The most important finding of the present study was the overall mean of Operational Performance, which was the highest in all the dimensions of production improvement. This means that the respondents believed that Artificial Intelligence was most useful in operational activities, such as production planning, workflow coordination, operational monitoring, productivity enhancement and managerial decision-making. The results indicate that AI is no longer just a tool for automation but an integral part of the operational processes in today's modern industrial landscape.

This high operational performance rating is indicative of the growing capabilities of Saudi industrial companies to benefit from Artificial Intelligence for operational monitoring and facilitation of the speed and accuracy of operational decisions. Through AI technologies, production data can be collected and analyzed continuously, enabling organisations to detect any problems in the production process right away, optimize production workflows, and enhance communication between different departments involved in production. As a result, manufacturing companies can be more proactive in meeting operational needs while improving continuously.

The results are also almost similar with study conducted by Dwivedi et al. (2021) highlighting that Artificial Intelligence plays a vital part in improving the organizational performance by improving the quality of a decision, enhancing the operational flexibility as well as analytical capabilities. Their research indicates that AI can help managers make evidence-based decisions for operations, based on real-time production data, not just on their own judgment. The current study confirms these findings, showing that companies in Saudi Arabia are increasingly leveraging AI as an intelligent decision-making tool.

Likewise, Frank et al. (2019) showed that the operational performance of manufacturing systems could be significantly enhanced by using the technologies of Industry 4.0, which include intelligent production monitoring, automated production process control, and continuous communication between production systems. They found that Artificial Intelligence and connected production environments can substantially minimise production delays, increase manufacturing responsiveness and boost manufacturing productivity. The results of the present study are reminiscent of these observations.

Similarly, Bag et al. (2021) found that the use of Artificial Intelligence enhances the operational capability of the organization through integration, flexibility, and coordination of processes and technologies. Organizations with intelligent manufacturing systems achieved higher operational efficiency and better responsiveness to the rapidly changing production requirements. The results of the particular survey support this result by highlighting that AI was seen as most effective in enhancing operational monitoring and workflow coordination.

Digital Transformation Theory can be used to explain the positive relationship between Artificial Intelligence and operational performance. Digital transformation is not just about the use of cutting-edge technology, it also entails a reimagining of business workflow, decision-making frameworks and communication channels. Artificial Intelligence is one of the main technologies that can facilitate this change as it transforms operational data into knowledge, which is directly applicable to enhance organizational performance.

In the Saudi industrial context, enhancing operational performance is more crucial than ever before due to the fact that industrial organizations are expected to compete with the rest of the world and at the same time support the national industrial development initiatives. These organizations are able to benefit from the advanced capabilities that AI offers in the field of production system management, to make their operations more transparent and efficient, and

to further increase organizational agility. The present results are thus of relevance for the empirical evidence of the strategic importance of AI in improving industrial operations.

In conclusion, the results suggest that AI plays a significant role in creating operational excellence by enhancing coordination within the organization, boosting manufacturing productivity, improving operational control, and enabling intelligent decision-making. As a result, AI technologies are expected to give Saudi industrial companies a higher performance in their operations than other companies that use traditional manufacturing processes more.

5.4. Product quality.

The other important result of the study was the positive influence of Artificial Intelligence on Product Quality, which was also statistically significant. The respondents indicated that AI technologies would help to increase the quality inspection, increase the production accuracy, decrease manufacturing defects, improve quality assurance procedures, and increase compliance with technical specifications. The results of this research show that AI has now entered the technological toolbox must-have building blocks of contemporary quality management systems.

The findings are consistent with the results of Kusiak (2018) who stated that AI can greatly improve manufacturing quality by implementing smart quality inspections and automated defect detection. The computer Vision Systems, with the help of Artificial Intelligence, can be able to examine manufactured products faster and more accurately than the manual inspection systems, says Kusiak. These intelligent systems reduce human error, as well as ensure manufacturing consistency and product reliability.

Likewise, Javaid et al. (2022) found that Artificial Intelligence can facilitate real-time analysis of production data for continuous quality monitoring during manufacturing processes. Their study showed that AI technologies can detect quality failures instantaneously, enabling them to take corrective measures before the defective products move to the next stage of

production. These conclusions are reinforced by the present findings, which show that the use of AI for quality management in industrial firms is becoming more prevalent in Saudi Arabia.

Moreover, the authors of the study by Bag et al. (2021) have pointed out that the use of the Internet of Things (IoT) technologies in the manufacturing process in combination with Artificial Intelligence (AI) technologies can significantly enhance the product quality by monitoring the manufacturing process continuously. Artificial Intelligence processes the operational data gathered by intelligent sensors and detects any abnormal production pattern or any deviations in the quality of the work produced. This integration allows for proactive quality management and not only on the postproduction phase.

The positive contribution of Artificial Intelligence to the quality of products can be read in the context of Industry 4.0 Theory, which considers intelligent quality management as one of the main benefits of a digital manufacturing environment. AI technologies empower continuous interaction between production equipment, quality monitoring systems and manufacturing databases, allowing for autonomous quality control during production. This means that businesses using AI technologies are more likely to produce consistent products and minimize defects and wasted time.

The results of the study are of significance for the industrial firms of Saudi Arabia because one of the main factors that determines the international competitiveness is product quality. With Saudi manufacturers getting more and more involved in global supply chains, they must meet with international quality standards. By enabling advanced capabilities such as predictive maintenance, quality control, and enhanced customer insights, Artificial Intelligence empowers manufacturing organizations to optimize production processes, reduce waste, and meet high-quality standards while delivering exceptional customer satisfaction.

In light of the current findings, it is, therefore, worth to mention that the implementation of AI adds great value to the enhancement of quality in industrial companies of Saudi Arabia so as to help them compete in the ever-increasing global market.

5.5. Production Cost Reduction

The results of the present study also showed that Artificial Intelligence has a statistically significant positive impact on Production Cost Reduction. The participants confirmed that AI technologies help lower maintenance expenses, lower equipment downtime, optimize resource use, decrease manufacturing waste, and boost organization profitability. These results show that Artificial Intelligence brings significant economic advantages to the table, alongside the boost in operational efficiency.

The findings align with the one of Lee et al. (2015) that predictive maintenance is among the most economically important areas of application of Artificial Intelligence in the manufacturing industries. Their study showed that predictive maintenance systems are always monitoring equipment conditions and predict mechanical failures in advance of breakdowns. This is a proactive measure that can significantly lower maintenance costs and enhance production continuity. Similarly, the present results suggest that users considered AI as an effective tool to lower maintenance expenses and increase the reliability of their equipment.

Frank et al. (2019) also found that Artificial Intelligence plays a role in cost optimization for production scheduling, inventory control, manpower utilization, and operational efficiencies. Intelligent optimization of manufacturing resources reduces the unnecessary operating costs and improves the production efficiency. The results of the current study confirm these conclusions and indicate that Saudi industrial companies are actively adopting AI to enhance their cost efficiency.

Likewise, Javaid et al. (2022) stated that Artificial Intelligence can lower manufacturing costs by optimizing resources with intelligence, automating production planning, predicting machine failures, and optimizing operation in real time. While there is a substantial initial investment in implementing AI, the long-term financial gains are substantial, with reduced operational costs, greater productivity, and enhanced manufacturing efficiency being just a few of the benefits.

In the context of the Resource-Based View (RBV), AI stands as a strategic asset that can enhance an organization's efficiency and provide a competitive edge. The best organizations that are using AI can streamline their own processes better than their competitors, leading to a decrease in operational expenses and an improvement in overall organizational performance.

The results are of special significance for Saudi Arabia as cutting production costs is among the main goals of the Saudi industrial modernization process as part of Saudi Vision 2030. The manufacturing sector that can benefit from the use of Artificial Intelligence to enhance operational efficiency is more likely to have enhanced its industrial competitiveness, boost exports, and participate in the national economic diversification.

Overall, the results show that Artificial Intelligence plays an important role in reducing production costs and enhancing manufacturing performance. The results further confirm earlier empirical studies and lend further credence to the role of Artificial Intelligence in the strategic relevance of the organizations in the Saudi industrial sector.

5.6. Research Hypotheses

All the research hypotheses tested by the statistical analyses in Chapter Four were confirmed. The primary hypothesis, which assumed that the use of Artificial Intelligence had a positive impact on production improvement, was accepted. Similarly, the four sub-hypotheses

related to production efficiency, operational performance, product quality and reduction in production cost were also confirmed.

The acceptance of the main hypothesis implies that AI is not a technology strictly related to certain activities but a way of being an organization that affects several aspects of manufacturing performance. This result aligns with the previous empirical studies that have reported positive correlations among the implementation of AI and organizational performance (Dwivedi et al., 2021; Javaid et al., 2022; Bag et al., 2021).

The support of the first sub-hypothesis shows that the integration of Artificial Intelligence can greatly enhance the efficiency of production, optimize the manufacturing processes and maximize the use of equipment. The second sub-hypothesis is proved as AI significantly enhances operational performance by facilitating intelligent monitoring and decision-making. The third sub-hypothesis suggests that AI boosts product quality by helping to improve inspection accuracy and minimize manufacturing defects. Lastly, the fourth hypothesis is supported by the evidence that AI plays a crucial role in reducing production costs by predicting maintenance needs and optimizing resource usage.

5.7. Implications

5.7.1. Theoretical Implications

This study has a number of important theoretical contributions to the current knowledge on the field of Artificial Intelligence (AI) and manufacturing management.

First, the results confirmed the Resource Based View (RBV) as an empirical basis, showing the potential of Artificial Intelligence (AI) as a useful resource for the organization that can lead to a sustainable competitive advantage. Organizations that had more advanced AI capabilities showed better production performance than those using traditional manufacturing technologies.

Second, the results confirm the Industry 4.0 Theory, as the implementation of intelligent manufacturing technologies contributes to production efficiency, operational performance, product quality and cost optimization through intelligent automation and decision based on data.

Third, the study adds to Digital Transformation Theory by substantiating that Artificial Intelligence (AI) enables organizational transformation beyond the mere implementation of technology to full operational transformation.

Lastly, the study adds to the small body of empirical research on Artificial Intelligence in Saudi Industrial Organizations, thus complementing the existing theoretical work of the implementation of AI in emerging industrial economies.

5.7.2. Practical Implications

It is important for industrial companies to still invest in the technologies of artificial intelligence, as they are able to greatly benefit the operational efficiency, productivity of manufacturing, improving the quality of the products, and cost optimization.

Continuous training programs to develop employees' AI skills should be promoted to strengthen the workforce development of the organizations. Human capital will always play a key role in harnessing maximum organizational benefits from the intelligent manufacturing technologies.

Moreover, AI should be seamlessly integrated with Enterprise Resource Planning (ERP), Manufacturing Execution Systems (MES), Supply Chain Management (SCM), and Quality Management Systems (QMS) to create completely smart manufacturing environments in industrial companies.

5.7.3. Managerial Implications

Managers need to understand that the application of Artificial Intelligence is a strategic investment, not just an operational technology. Senior leadership need to integrate AI adoption

into their strategic planning for their organization and invest in the resources (time and money) needed to complete digital transformation effectively.

AI can be used by production managers to enhance the responsiveness and competitiveness of manufacturing by scheduling production processes, optimizing inventory, monitoring the state of manufacturing processes, and predicting their breakdowns.

Managers should also foster organizational cultures that are conducive to innovation, lifelong learning, technology adaptation, and cross-functionality. Organizations in such settings can see that the implementation of Artificial Intelligence is efficient and productive to a large extent.

Chapter Summary

This chapter discussed the findings of the study and compared the findings with the previous empirical studies and theoretical views. The discussion reaffirmed that the use of Artificial Intelligence in Saudi industrial companies is highly beneficial to the production efficiency, operational performance, product quality and reducing production costs. The results confirmed all the research hypotheses and showed empirical evidence that is in line with RBV, Industry 4.0 Theory, and Digital Transformation Theory.

The chapter also discussed the theoretical, practical, and managerial implications of the implementation of AI in the industrial organizations and shared recommendations for industrial organizations, policymakers, and researchers. In conclusion, the discussion highlighted how Artificial Intelligence is a strategic organizational capability that can revolutionize manufacturing processes and bolster industrial competitiveness in Saudi Arabia.

The results of the entire study are outlined, the main findings summarized, the limitations of the study identified and suggestions for further study offered in the following chapter.

CHAPTER SIX

6. CONCLUSIONS AND RECOMMENDATIONS:

Introduction

This dissertation concludes with the overall conclusions from the empirical investigation carried out during this research in the last chapter. It summarizes the key results derived from the statistical analysis and discusses the implications of these findings in terms of the research goals, theory and literature. Chapter Four presented the results of the statistical analysis, while Chapter Five interpreted the results based on the comparison with previous studies and theoretical approaches, the present chapter combines all the results to get a comprehensive vision of the role of Artificial Intelligence in enhancing the production in the Saudi industrial companies. Moreover, this chapter presents the academic, practical, managerial, and policy implications of the research, the main limitations faced in the study, and suggestions for future research directions and implications for the industrial organizations.

In this context, the introduction of Artificial Intelligence has revolutionized manufacturing industries worldwide, the implementation of which has paved the way for the development of intelligent production systems that have the capacity to make autonomous decisions, predict and monitor production processes, manage product quality intelligently and optimize production processes continuously. This is because in today's dynamic global environment, with fast-paced technological growth, manufacturing organizations are increasingly vying with each other, and AI is one of the most important organizational strengths that enables them to achieve operational excellence and sustainable competitive advantage. The use of Artificial Intelligence (AI) has expanded significantly after the launch of Saudi Vision 2030, which focuses on industrial diversification, digital transformation, technological innovations and intelligent manufacturing as key pillars for achieving long-term national economic development in the Kingdom of Saudi Arabia.

6.1. Summary of the Study

The present study aimed to examine the level of Artificial Intelligence's role in enhancing the production performance in Saudi industrial companies. Specifically, four key dimensions of production improvement – production efficiency, operational performance, product quality, and reduction in production costs – were explored in the study to identify the impact of the use of Artificial Intelligence on these four aforementioned areas. The study adopted a quantitative research methodology with 150 managers, engineers, supervisors, and technical employees to gather empirical evidence on the application of Artificial Intelligence in industrial manufacturing in Saudi Arabia.

The results across all of the dimensions investigated were always the same in that Artificial Intelligence can be used to significantly improve manufacturing performance. More significantly, the findings showed that AI is no longer the next big technological trend but rather a strategic capability of the organization that has the potential to change the nature of production systems, organizational flexibility, organizational responsiveness, and sustainable industrial competitiveness. Based on this research, the results have implications for both theory and practice for manufacturing organizations aiming to develop their digital transformation efforts while also fulfilling the visions and goals of Saudi Vision 2030.

AI has become one of the most disruptive technologies for the Fourth Industrial Revolution (Industry 4.0) and for manufacturing systems today. Industrial operations are becoming more complex, as the competition is rising, and as customer expectations are growing faster than ever, all while technology advances rapidly, making it an attractive opportunity for manufacturing organizations to invest heavily in Artificial Intelligence (AI) technologies that can enhance operational efficiency, manufacturing productivity, product quality, resource utilization, and production costs. While many international studies have studied Artificial Intelligence in manufacturing settings, there is limited empirical studies that

have considered the overall effect of Artificial Intelligence on production improvement in Saudi industrial companies. This study was therefore carried out to fill this significant gap in the knowledge.

The main goal of the study was to analyze the role of Artificial Intelligence in enhancing the production in the industrial companies in the Kingdom of Saudi Arabia. For that, a wide survey of the theoretical and empirical literature was carried out that includes all the relevant fields of Artificial Intelligence, Industry 4.0, intelligent manufacturing systems, production improvement, and digital transformation. Given this review, a conceptual framework was developed, which suggests that Artificial Intelligence positively affects four main aspects for improving production: production efficiency, operational performance, product quality, and reducing production costs.

In terms of methodological, the study used quantitative research method, positivist philosophy in the research and the deductive approach in the research. The cross sectional survey design was used to gather primary data from managers, engineers, supervisors and technical employees in the industrial firms in Saudi Arabia, by distributing a structured questionnaire. The sampling method used was simple random sampling and valid responses obtained were 150, which were suitable for statistical analysis. The data collected were subjected to descriptive statistics, reliability analysis, Pearson correlation analysis, multiple regression analysis and Analysis of Variance (ANOVA) were used for the analysis of the collected data in SPSS Version 29.

The results showed that the relationships between Artificial Intelligence adoption and the dimensions of production improvement were all found to be positive and consistent. Artificial Intelligence (AI) was widely used in organizations, with high levels of implementation of intelligent automation, production monitoring, predictive analytics and operational decision making. The statistical analyses also showed that Artificial Intelligence

truly aids in enhancing the production efficiency, maximizing the utilization of machinery and equipment, and minimizing production downtime. Operational performance showed the most improvement, signifying that Artificial Intelligence has the most impact on manufacturing planning, monitoring, coordination of workflows, and organizational decision making. Likewise, Artificial Intelligence has improved the quality of the products by providing intelligent inspections systems and continuous quality monitoring, while also cutting costs in production by predictive maintenance, optimized resource allocation and reduced operational waste.

This is all taken together as proof that AI has emerged as an essential strategic capacity that enables the competitiveness and excellence of industrial processes, as well as the development of sustainable manufacturing in Saudi Arabia. The study thus offers empirical evidence of direct links between successful implementation of Artificial Intelligence and higher manufacturing performance and the national goals of digital transformation and industrial modernization of Saudi Vision 2030.

6.2. Conclusions

Based on the results of the present study, it could be concluded that AI is one of the most influential technologies that supports industrial production and competitiveness of industrial firms in Saudi Arabia, which could be considered as empirical evidence. The statistical analyses proved that there is a positive correlation between the adoption of Artificial Intelligence and production efficiency, operational performance, product quality and production cost reduction. Altogether, these results suggest that Artificial Intelligence (AI) is no longer a technology used for supporting operations but a strategic organizational capability that can transform manufacturing systems and enhance long-term organizational performance.

The study showed that Saudi industrial organizations have embraced more and more AI technologies in their digital transformation efforts. This result is an acknowledgment of the major technological advances the Saudi industrial sector has made in recent years, and since the start of Saudi Vision 2030. The growing adoption of intelligent manufacturing technologies, predictive analytics, machine learning, robotics, and intelligent automation suggests that Saudi industrial companies see the potential of AI as a key enabler for operational excellence and maintaining their competitiveness in global manufacturing markets.

The other important finding is that Artificial Intelligence has a strong impact on the efficiency of production. The results show that the use of AI technologies has a significant impact on production scheduling optimization, equipment utilization, reduction of production downtime, reduction of manufacturing waste and productivity improvement in production. The enhancements are proof that intelligent manufacturing systems allow companies to achieve maximum production and at the same time minimize production inefficiencies. Hence, Artificial Intelligence plays a significant role in enhancing manufacturing capacity and performance.

The study also found that the operational performance is the most affected by Artificial Intelligence. Operational performance was the highest overall rated dimension of production improvement among the ones investigated. The discovery indicates that intelligent manufacturing technologies play a particularly important role in enhancing production monitoring, operational coordination, production workflow, manufacturing flexibility, and management decision making. By continually tracking manufacturing processes and analyzing operational data on-the-fly, Artificial Intelligence helps firms discover operational issues sooner and take corrective action before the efficiency of manufacturing is compromised. These skills greatly enhance operational responsiveness and manufacturing efficiency.

The results also confirm that AI plays an important role in the enhancement of product quality. By utilizing computer vision, machine learning, and predictive analytics, manufacturing companies can more accurately detect production errors and keep the manufacturing process more consistent. Instead of the traditional inspection methods, organizations using Artificial Intelligence continuously check the manufacturing quality during the manufacturing process, thus minimizing defective products and customer satisfaction. As a result, AI contributes to the improvement of the company's reputation and to reinforcing its competitive position in increasingly competitive international markets.

Another Key benefit of the implementation of Artificial Intelligence was "Production Cost Reduction". The study validated that AI technologies can greatly cut down on maintenance-related costs, increase the reliability of equipment, optimize the use of manufacturing resources, cut down production waste, and reduce operational downtime. These results show that, while there is a significant upfront investment to implement Artificial Intelligence, the operational and financial gains are more than significant in the long term. So, AI should be considered an investment that can create long-term economic value, not just a technology spend.

When taken together, these results show that AI applies to a broad range of manufacturing aspects, not specific operational activities. The study thus shows that Artificial Intelligence implementation in successful organizations leads to organizational improvements that are integrated throughout production efficiency, operational effectiveness, quality management, and cost optimization. Finally, such extensive organizational improvement enhances industrial competitiveness and contributes to sustainable industrial development.

Lastly, the theoretical frameworks that support this research, such as the Resource Based View (RBV), Industry 4.0 Theory and Digital Transformation Theory, are suitable to explain the organizational benefits created as a result of implementation of Artificial

Intelligence. AI is a treasure trove of organizational resources that can enhance manufacturing capabilities, as well as support digital transformation and intelligent industrial development. Thus, the findings of the study contribute to the theoretical framework, and the study has given more empirical evidence in the Saudi industrial environment.

6.3. Study Contributions:

The current study has important implications for research, practice, management, and policy. The contributions go beyond the conclusions of this study and offer important guidance for researchers, manufacturing companies and policymakers engaged in the process of digital transformation in industry.

6.3.1. Academic Contributions

The study adds to the existing body of knowledge about Artificial Intelligence (AI) and manufacturing management from an academic point of view by offering empirical evidence from the Saudi industrial sector. There have been many studies abroad that explored the application of Artificial Intelligence in developed countries, and very few studies that have focused on the Saudi industrial organizations. The research thus filled an important geographical gap in the existing literature and added to the existing knowledge on the implementation of AI in emerging industrial economies.

In addition, the study makes a theoretical contribution by bringing together three complementary theories that are the Resource Based View (RBV), Industry 4.0 Theory, and Digital Transformation Theory. The present research does not intend to adopt any single theory of the problem, instead, it proves that these theories as a whole can explain mechanisms of how the Artificial Intelligence has improved the manufacturing performance. This integrated theoretical view gives a fuller idea of the implementation of Artificial Intelligence in today's industrial organizations and proves to be a great conceptual background for upcoming research on the field.

The research is also methodologically important as it creates and empirically tests a conceptual model that connects the uptake of Artificial Intelligence with four main dimensions of production improvement. The proposed framework can thus be used as a guideline for future studies of the implementation of AI in manufacturing companies in other industrial sectors and regions.

6.3.2. Practical Contributions

The research offers valuable practical implications for manufacturers aiming at enhancing operational performance via intelligent technologies. The empirical results show that the use of Artificial Intelligence has a great effect on production efficiency, operational performance, production of quality products, and reduction of production costs. The results offer valuable, fact-based data for manufacturing companies to support their investment decisions in AI technologies.

Industrial managers can use the results to support investments in intelligent automation, predictive maintenance, computer vision technologies, machine learning applications and advanced manufacturing analytics. AI should not just be seen as a fledgling technological trend, but as a strategic tool that can enhance an organization's overall performance and competitiveness.

Furthermore, the research highlights the need for ongoing employee training when implementing Artificial Intelligence. Therefore, in addition to technological investments, manufacturing organizations need to invest in building the skills of their employees to operate ever more intelligent production systems.

6.4. Recommendations

To achieve this, the study provides several recommendations based on the empirical findings and conclusions, which are necessary to enhance the implementation and use of Artificial Intelligence in Saudi industrial companies.

First, industrial entities need to keep investing in Artificial Intelligence technologies in all aspects of production. It is recommended to use AI for production planning, equipment monitoring, predictive maintenance, quality inspection, inventory management, logistics coordination and operational decisions. The full integration of Artificial Intelligence into organizational processes will maximize the benefits of operations and will have a great impact on the manufacturing's competitiveness in the future.

Secondly, the production companies must improve their employee training and professional development initiatives with regard to the Artificial Intelligence skills. Employees should be provided with ongoing training on the use of machine learning, predictive analytics, robotics, industrial automation, intelligent manufacturing systems, and digital decision supporting technologies. Organizations can maximize the capabilities of Artificial Intelligence and minimize risks of implementing new technologies with continuous workforce development.

Third, there should be an increase in predictive maintenance programs with the aid of Artificial Intelligence for organizations. Predictive maintenance can substantially decrease equipment failures, enhance machine reliability, lower maintenance costs, and minimize downtime. So, predictive maintenance should be a key element of intelligent manufacturing approaches.

Fourth, manufacturing companies need to create a digital manufacturing system that integrates Artificial Intelligence with Enterprise Resource Planning (ERP), Manufacturing

Execution Systems (MES), Supply Chain Management (SCM), Internet of Things (IoT), cloud computing, and industrial data platforms. Integrated digital environments provide a significant operational benefit in terms of operational coordination and allow real-time optimization of manufacturing.

Fifth, organizations should regularly review the performance of organizations, based on the implementation of Artificial Intelligence with comprehensive performance measurement systems. The indicators used to monitor performance should include measures of production efficiency, product quality, operational performance, maintenance effectiveness, equipment use, customer satisfaction and financial performance. On-going assessment allows organizations to pinpoint areas for improvement and maximize ROI on Artificial Intelligence investments.

Sixth, the government should provide ongoing financial incentives and growth support for national industrial digital transformation; build technological infrastructure; provide regulatory support for industrial digital transformation; and continue conducting joint research and development programs. These efforts will help in speeding up the adoption of Artificial Intelligence and enhance the competitiveness of Saudi manufacturing industries.

Last but not least, universities and research institutions must increase cooperation in conducting joint research projects with manufacturing companies to create applications for Artificial Intelligence specifically tailored to the operational issues faced by Saudi manufacturing companies. Increased collaboration between academia and industry will make a tremendous impact on technological innovation and the development of sustainable industry.

6.5. Study Limitations

The present study was able to achieve its objectives, collect some empirical evidence on the role of Artificial Intelligence in enhancing production in the Saudi industrial companies, but several limitations should be noted. It is essential to acknowledge these constraints because

it enables future investigators to further the work of the present investigator and deal with problems that might not have been fully investigated in the present study.

The first constraint is geographical, meaning that the study is limited by geographical areas. This study was carried out only with industrial companies that are situated in the KSA. The industrial organization, technological level, government policy, and industrial activities are different between countries, even though Saudi Arabia is one of the most rapidly expanding industrial economies in the Middle East. Therefore, the results need to be interpreted with care when assuming they are applicable to other manufacturing companies from other economic, cultural or regulatory backgrounds. Comparative studies of several countries conducted in the future can provide more evidence of the impact of AI on manufacturing performance.

Another drawback is related to the research design. The study used a cross-sectional survey method in which the data collection was carried out at one point in time. This methodology was suitable for discovering relationships among the study variables but was not able to detect temporal changes in the implementation of Artificial Intelligence. The road to the adoption of Artificial Intelligence is dynamic and the benefits for the organization may grow with the maturation of technology and experience of the organizations. Thus, the longitudinal research designs would show the long-term impact of Artificial Intelligence on the performance of manufacturing.

Another constraint is the data collection technique. The study was largely dependent on self-reports of managers, engineers, supervisors and technical staff through questionnaires. While respondents had been deemed knowledgeable about the production activities of their organizations, perception-based data can be subject to personal opinion, organizational culture, and/or response bias. Future studies can enhance empirical evidence by using questionnaire-based data along with some objective organizational performance indicators, including

production output, equipment downtime, maintenance information, quality defect rates, operational efficiency indicators, and financial performance measures.

A further limitation of the sample size is also present. The number of respondents ($n = 150$) was large enough for the analytical methods used in the present study, but a larger sample size across a wider range of industrial sectors would enhance the generalizability of the findings. It would be beneficial to include a wide range of organizations in terms of their size, ownership, and technological maturity to give a broader picture of the diffusion of Artificial Intelligence in manufacturing in Saudi Arabia.

In addition, the present study specifically concentrated on four areas of production improvement: production efficiency, operational performance, product quality and production cost reduction. These dimensions are relevant to manufacturing performance and important to consider, but the current study found that Artificial Intelligence can have an impact on many other organizational outcomes that were not investigated. These encompass innovation capability, organizational agility, environmental sustainability, employee creativity, supply chain resilience, customer satisfaction, financial performance and organizational learning. Further investigations of these other aspects in future research could further contribute to the understanding of the implementation of Artificial Intelligence.

Lastly, only Artificial Intelligence was considered as the main independent variable in the study. Today's factories are increasingly adopting a variety of Industry 4.0 technologies such as Internet of Things (IoT), Big Data Analytics, Cloud Computing, Blockchain, Cyber-Physical Systems, Autonomous Robots, Digital Twins and Additive Manufacturing. The study of the combined effects of these complementary technologies can offer a better understanding of intelligent manufacturing systems than the study of Artificial Intelligence alone.

Although it has certain restrictions, the study's findings are powerful empirical evidence related to the role of Artificial Intelligence in boosting the production of industrial companies in Saudi Arabia. The restrictions listed above should not be considered as "negatives" that reduce the significance of the present study, but rather as suggestions for further research.

Finally, the present study contributes to the literature in Artificial Intelligence and manufacturing management, both theoretically, empirically and practically. It provides an in-depth analysis on the impact of Artificial Intelligence on production improvement in the Saudi industry sector and suggests evidence-based recommendations for the managers, policy makers, and researchers in the sector. The outcomes of this research are expected to aid in future academic investigations and help industrial companies in the Kingdom of Saudi Arabia to formulate efficient Artificial Intelligence strategies for improving the operational performance, competitiveness and sustainable growth of Industrial sectors.

7. References

- Acemoglu, D., & Restrepo, P. (2020). Artificial intelligence, automation, and work. *Journal of Economic Perspectives*, 33(2), 3–30. <https://doi.org/10.1257/jep.33.2.3>
- Bag, S., Pretorius, J. H. C., Gupta, S., & Dwivedi, Y. K. (2021). Role of institutional pressures and resources in the adoption of big data analytics powered artificial intelligence, sustainable manufacturing practices and circular economy capabilities. *Technological Forecasting and Social Change*, 163, 120420. <https://doi.org/10.1016/j.techfore.2020.120420>
- Brynjolfsson, E., Rock, D., & Syverson, C. (2019). Artificial intelligence and the modern productivity paradox: A clash of expectations and statistics. *The Economics of Artificial Intelligence*, 23–57. <https://doi.org/10.7208/chicago/9780226613475.003.0002>
- Chui, M., Manyika, J., & Miremadi, M. (2016). Where machines could replace humans—and where they can't (yet). *McKinsey Quarterly*, 3, 58–69.
- Davenport, T. H., & Ronanki, R. (2018). Artificial intelligence for the real world. *Harvard Business Review*, 96(1), 108–116.
- Dwivedi, Y. K., Hughes, L., Ismagilova, E., Aarts, G., Coombs, C., Crick, T., & Williams, M. (2021). Artificial intelligence (AI): Multidisciplinary perspectives on emerging challenges, opportunities, and agenda for research. *International Journal of Information Management*, 57, 101994. <https://doi.org/10.1016/j.ijinfomgt.2019.08.002>
- Frank, A. G., Dalenogare, L. S., & Ayala, N. F. (2019). Industry 4.0 technologies: Implementation patterns in manufacturing companies. *International Journal of Production Economics*, 210, 15–26. <https://doi.org/10.1016/j.ijpe.2019.01.004>
- Ivanov, D., Dolgui, A., & Sokolov, B. (2019). The impact of digital technology and Industry 4.0 on the ripple effect and supply chain risk analytics. *International Journal of Production Research*, 57(3), 829–846. <https://doi.org/10.1080/00207543.2018.1488086>

- Jordan, M. I., & Mitchell, T. M. (2015). Machine learning: Trends, perspectives, and prospects. *Science*, 349(6245), 255–260. <https://doi.org/10.1126/science.aaa8415>
- Kamble, S. S., Gunasekaran, A., & Sharma, R. (2018). Analysis of the driving and dependence power of barriers to adopt Industry 4.0 in Indian manufacturing industry. *Computers in Industry*, 101, 107–119. <https://doi.org/10.1016/j.compind.2018.06.004>
- Kusiak, A. (2018). Smart manufacturing. *International Journal of Production Research*, 56(1–2), 508–517. <https://doi.org/10.1080/00207543.2017.1351644>
- Lee, J., Bagheri, B., & Kao, H. A. (2015). A cyber-physical systems architecture for Industry 4.0-based manufacturing systems. *Manufacturing Letters*, 3, 18–23. <https://doi.org/10.1016/j.mfglet.2014.12.001>
- Li, L. (2018). China’s manufacturing locus in 2025: With a comparison of “Made-in-China 2025” and “Industry 4.0”. *Technological Forecasting and Social Change*, 135, 66–74. <https://doi.org/10.1016/j.techfore.2017.05.028>
- Lu, Y. (2017). Industry 4.0: A survey on technologies, applications and open research issues. *Journal of Industrial Information Integration*, 6, 1–10. <https://doi.org/10.1016/j.jii.2017.04.005>
- Manyika, J., Chui, M., Bughin, J., Woetzel, J., Batra, P., Ko, R., & Sanghvi, S. (2017). Artificial intelligence: The next digital frontier? *McKinsey Global Institute Report*.
- Porter, M. E., & Heppelmann, J. E. (2017). Why every organization needs an augmented reality strategy. *Harvard Business Review*, 95(6), 46–57.
- Rai, A., Constantinides, P., & Sarker, S. (2019). Next-generation digital platforms: Toward human–AI hybrids. *MIS Quarterly*, 43(1), iii–ix.
- Schwab, K. (2016). The fourth industrial revolution. *World Economic Forum*.

Wang, S., Wan, J., Li, D., & Zhang, C. (2016). Implementing smart factory of Industry 4.0: An outlook. *International Journal of Distributed Sensor Networks*, 12(1).
<https://doi.org/10.1155/2016/3159805>

Zhong, R. Y., Xu, X., Klotz, E., & Newman, S. T. (2017). Intelligent manufacturing in the context of Industry 4.0: A review. *Engineering*, 3(5), 616–630.
<https://doi.org/10.1016/J.ENG.2017.05.015>

8. APPENDIX: QUESTIONNAIRE

Variable	Item	1	2	3	4	5
Artificial Intelligence Adoption	Our company implements artificial intelligence technology in its production process.	☐	☐	☐	☐	☐
Artificial Intelligence Adoption	Artificial intelligence technology is incorporated in our production systems.	☐	☐	☐	☐	☐
Artificial Intelligence Adoption	Due to AI technology, our company is able to effectively analyze its production data.	☐	☐	☐	☐	☐

Artificial Intelligence Adoption	Our company is able to analyze its production data effectively due to our investment in advanced AI technology.	☐	☐	☐	☐	☐
Artificial Intelligence Adoption	Due to AI technology, there is greater automation in the production process.	☐	☐	☐	☐	☐
Production Efficiency	Production efficiency is improved with the use of artificial intelligence technology.	☐	☐	☐	☐	☐
Production Efficiency	Production errors are reduced with	☐	☐	☐	☐	☐

	the use of AI technology.					
Production Efficiency	Production scheduling is improved with the use of AI technology.	☐	☐	☐	☐	☐
Production Efficiency	The utilization of equipment is improved with the use of AI technology.	☐	☐	☐	☐	☐
Production Efficiency	The output of production is increased with the use of AI technology.	☐	☐	☐	☐	☐
Operational Performance	The operational decision making is improved with the use of	☐	☐	☐	☐	☐

	artificial intelligence.					
Operational Performance	The operational productivity is increased with the use of AI technology.	☐	☐	☐	☐	☐
Operational Performance	The monitoring of the production process is improved with the use of AI technology.	☐	☐	☐	☐	☐
Operational Performance	The production planning is improved with the use of AI technology.	☐	☐	☐	☐	☐
Operational Performance	The overall operational performance is	☐	☐	☐	☐	☐

	improved with the use of AI technology.					
Product Quality	The quality of the product is improved with the use of AI technology.	☐	☐	☐	☐	☐
Product Quality	The detection of manufacturing defects is improved with the use of artificial intelligence.	☐	☐	☐	☐	☐
Product Quality	The quality control process is improved with the use of AI.	☐	☐	☐	☐	☐
Product Quality	The production waste is	☐	☐	☐	☐	☐

	reduced with the use of AI.					
Product Quality	The operational cost is reduced with the use of AI technology.	☐	☐	☐	☐	☐
Cost Reduction	The maintenance cost is reduced with the use of AI technology.	☐	☐	☐	☐	☐
Cost Reduction	The downtime of the machine is reduced with the use of AI technology.	☐	☐	☐	☐	☐
Cost Reduction	The utilization of resources is improved with the use of AI.	☐	☐	☐	☐	☐

Cost Reduction	With the use of AI technology, the profit is increased.	☐	☐	☐	☐	☐
Cost Reduction	Item	☐	☐	☐	☐	☐

8.1.1. Demographic Information

Question	Options
Gender	Male Female
Age	Less than 30 / 30–40 / 41–50 / Above 50
Education Level	Bachelor Master PhD
Job Position	Manager Engineer Supervisor Technician
Years of Experience	Less than 5 / 5–10 / 11–15 / More than 15
Industrial Sector	Manufacturing / Technology / Energy