CHALLENGES FACING BY INDUSTRY LEADERS IN IMPLEMENTATION OF AI WITHIN MANUFACTURING ENVIRONMENTS

by

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(Under the Direction of Beshoy Morkos)

ABSTRACT

This thesis focuses on the role and impact of Artificial Intelligence (AI) and automation in manufacturing. The advancements of AI will significantly improve effectiveness and reduce inefficiency within the present framework, integrating AI into existing systems is not without challenges. This thesis work primarily focuses on the difficulties occurring in modern industry, technological and financial aspects, the adaptation of workers, and information protection. It also analyses these existing challenges and limitations in a detailed manner, presenting measures for the smooth deployment of AI and automation technologies within the industrial sector. Thus, this thesis will provide more insight into improving the knowledge on how to create better and more resistant industrial systems with the help of intelligent technologies.

INDEX WORDS: Artificial Intelligence (AI), Automation. Smart Manufacturing, Industry 4.0, Mask R-CNN, Productivity, Efficiency, Data Security, Workforce Adaption, Integration Challenges, Technological Barriers, Food Processing, Waste Management.

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DEDICATION

I dedicate this thesis to my parents and family. Your support and encouragement have been the foundation of my journey. Thank you for sharing my interests and making it possible for me to pursue a Master's in Artificial Intelligence. I also thank my friends for their constant support and belief in me. Your help has been invaluable. Thank you for standing by me and making this achievement possible.

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CHAPTER 1

INTRODUCTION

Automation and artificial intelligence have completely changed the manufacturing sector by delivering new levels of productivity, precision, and efficiency. This is an example of Industry 4.0, which is a transition to intelligent manufacturing using integrated technology and processes to reduce human labor and automate solutions (18). These technologies greatly enhance production efficiency, reduce operating costs, minimize human errors, and optimize product quality through analysis and interpretation of massive datasets.

The integration of advanced technologies in the manufacturing environment brings to emerge several challenges. The identification of challenges in the industry includes technical and financial barriers, the necessity for workforce adaptation, and data security risks. (9) All these are highlighted in the current thesis, showing effective ways to manage the challenges of implementing AI and automation in manufacturing while maximizing their potential. The current AI models and strategies are optimized in such a way in this research that it could enable production efficiency and build the way for more robust and innovative manufacturing systems. These topics coincide with the thesis statement: "What are the primary challenges facing by industry professionals in implementing AI and automation systems within manufacturing environments, and how can these obstacles be effectively addressed to optimize production and efficiency?"

This study will provide helpful recommendations and insights into adopting AI and automation for manufacturing companies to increase their productivity and competitive advantage.

1.1. Research Objective

The primary aims of the current thesis are to address the practical struggles faced by professionals to synchronize the usage of Artificial Intelligence (AI) and automation with the manufacturing operations systematically. The examination aims to identify the reasons behind barriers to technical progress that could enhance care, like not having money to commit, workforce issues, or concerns about security. The precise objectives of this project are four:

Key Challenges Identification & Analysis: It would systemically identify those top issues in application of AI and automation technology into manufacturing on an overall basis, such as high cost, integration complexity, skilled personnel shortage, data security.

Assess the Effect on Manufacturing & Efficiency: For examining how these challenges impact global production & efficiency in manufacturing processes. These tasks also include the assessment of effects if these barriers are not dismantled properly.

Propose solutions and strategies: To address these challenges and develop the way for easy integration of AI and automation technologies, suggest some solutions and strategies. This means looking at the solutions that already exist and even to take lead in some new innovative ways.

Recommend Best Practices: To develop best practices that can help manufacturing companies navigate the challenges of adopting automation and artificial intelligence while ensuring that these technologies are used to improve productivity and operational resilience.

Using this balanced investigation, the thesis will add to the collection of information regarding intelligent automation optimization of manufacturing processes, thereby opening the door to more innovative, productive, and efficient production systems.

CHAPTER 2

LITERATURE REVIEW

In my opinion, it remains clear that AI is an essential element that can be incorporated into the economy to enhance productivity in several industries while promoting sustainable development. Furthermore, what have been identified from the research of Deng, Y., & Wang, H. (2019) include, Procedures might be fully automated or made more efficient and productive, in addition to providing intelligent decision-making to the sectors, which already exist. However, there are some problems associated with it such as an individual's failure to find a way to use it appropriately, and the challenge of integrating the new technology in firms that belong to a pre-existing industry (1). The authors have strongly pointed out that in opposite to what is currently known about AI, it has to meet social and environmental needs and has to also rebuild the economy. Some of how it can be done is an example of smart health, something that is in connection with economy, also an example of something that increases stability and focuses on ways to work which are environmentally friendly and an example of smart city and AI in farming. Based on this comprehensive analysis, one can understand the impact of AI on economic growth and risks and opportunities of incorporating digital solutions in an organization (1,8). Here are some specific barriers and approaches for implementing AI in manufacturing.

China's AI Progress: The paper also discusses the fact that since the beginning of recent years, China has stepped up the pace of the application of AI; it states that

production begins ‘to shift away from human labor’ We can judge that this kind of development is most important for China’s continuous stable economic growth, and it is also considered as the necessity for the improvement of social productivity.

The economic challenges of AI: Some of the threats and risks faced in integrating AI in the economy are known as follows: The implementation of AI is done slowly, the socio-economic and political goals and directions of China need to be changed, the quality of education is declining, Job losses due to the introduction of AI technology. (1, 5)

Artificial Intelligence Integration Units: The current research paper outlines specific and distinct areas where AI is experiencing considerable progress in the following ways: (1)

- Intelligent Medical Health: Artificial intelligence is applied in diagnosing diseases and treatment processes.
- Intelligent Cities: AI is used in the management and development of cities.
- Intelligent Retail: It uses AI to automate processes and link web systems to transform retail.
- Intelligent Education: In this case, AI improves education standards in teaching and the performance of learners.
- Intelligent Agriculture: This is true because the use of AI enhances efficiency in production due to the automation of farming and its remote control.
- Intelligent Transportation: The impact of AI creates control and sensing systems in transport.

- Integration Strategies: This paper makes suggestions on how to apply Artificial Intelligence to the economy more effectively:
- Training in Intelligent Manufacturing: It demonstrates the potential of education in AI applications in the increasing manufacturing leading to faster economic development.
- AI in Traditional Industries: This discusses how to ensure that traditional industries adopt AI to ensure that the industries remain relevant in the market.
- Improving AI Manufacturing Services: As for the key measures to promote AI-based solutions into business processes, it outlines the improvement of AI service management.
- Economic Impact of AI: Thus, with total economic value optimization and the transition to a more reasonable economic development, AI contributes to improved organizational efficiency, proper utilization of resources, and product development in the economy.

Solutions to AI Integration Challenges Include: (1, 3, 7)

- Training and Skills Development: Realizing that companies are still struggling to fully leverage on AI in their operations, the paper closely discusses about training employees in the field.
- Modernizing Traditional Sectors: It allows for the utilization of AI in updating traditional industries to deal with new financial conditions and move past issues with old processes.

- Enhancing AI Manufacturing Support: One way to do this is to strengthen the AI service management, which is an important component of the described approach and helps to enhance the AI manufacturing support services.
- Developing Specialized AI Teams: The paper recommends such groups whose main role is to ensure they incorporate AI in the economy in an efficient manner and make positive economic impacts.
- Using AI to Optimize Resources: Optimal use of resources in the economy means reduction of waste and thus increasing efficiency.
- Promoting Innovation: In this regard, the study identifies issues with underutilization of technology and calls for a culture of innovation, especially in the application of AI in the traditional manufacturing industry and in other fields.

2.1 Introduction to AI in Manufacturing

The paper "Opportunities and Challenges to Integrate Artificial Intelligence into Manufacturing Systems" focuses on how recent developments of artificial intelligence, has various opportunities in enhancing efficiency, product quality, and revenue of manufacturing systems. In recent times, we have seen an increase use of technology to support manufacturing (45, 48), intelligence assistance (46, 47), and computational tools (49 - 51). However, we have experienced a recent surge in the role of AI in manufacturing environments (52), including manufacturing education (53-55).

During their informative and engaging panel discussion, Koval.enko, Barton, Moyne, and Tilbury provided an outlook on how AI could potentially revolutionize the manufacturing systems as well as some of the issues in this field. The authors also reviewed how AI can be applied to change the manufacturing paradigm so that it

incorporates customization, precision and adaptability. But they also pointed out various concerns they consider crucial to overcome for achieving these opportunities. Some of these challenges include how to enable easy integration of the AI with the operators, establishing infrastructure that will accommodate advancement AI capabilities and features, and providing means for cooperation between universities, industrialists, and government.(9) The authors underscored the importance of the stated milestones to succeed in utilizing AI as a way of enhancing productivity, quality as well as profitability in manufacturing, marking a shift towards intelligent manufacturing systems. This discussion clarifies the potential and complex dynamics that characterize the current state of AI in manufacturing.

They talked about the AI in manufacturing by highlighting several general areas of the panel discussion on the prospects of industry experts to successfully apply AI and automation systems within manufacturing settings, as well as the possible problems faced in implementing these ideas, (9, 17) and how these issues should be handled to achieve maximum productivity.

Human-AI Collaboration:

Existing Gaps: Existing AI in manufacturing is still basic and non-fully interactive, constantly responding to human control or failing to update its parameters accordingly. This makes them somewhat rigid to use in complex manufacturing situations. Autor further argue that (9) *““Most AI deployed in manufacturing plants today is relatively fixed, it does not have the ability to learn beyond what it has been trained to do, nor can it ask questions when it does not understand what to do."*

Suggested Improvements: Designing intelligent systems that could learn in both directions and interact with human operators to make the systems more sensitive and

efficient. (9) Asking and answering questions that would increase the intelligibility within the manufacturing processes.

Infrastructure Limitations:

Challenge: Most manufacturing systems are not ready to adopt and implement top-notch AI applications because they lack proper infrastructure such as efficient data collection system, integration capabilities and sufficient sensors to capture detailed process information. (9,15)

Advancements needed: Transforming and improving the technological framework to include efficient data acquisition and analysis methods. Improving sensors and incorporating the internet of things devices enable the provision of the data required for complex AI applications. (9,15)

Data Management and Utilization:

Challenge: Manufacturing systems produce large volumes of data, but this data is usually unorganized and not well preprocessed for use in AI applications. Data are often isolated and not well formatted. Autor explains that (9) *"Many manufacturing plants operate multiple shifts per day or even 24/7, leading to huge volumes of data. AI technology needs data to learn, and although there are a lot of data to be found in manufacturing systems, they are not always AI ready."*

Approach: Ensuring that standardized data management systems and procedures are adopted to enhance the quality as well as the retrievability of data. Making data formats suitable for AI and ensuring that data is collected with standardized procedures will help in efficient use of data analysis decision making. (9,16)

Economic and scalability Issues:

Barrier: The expense of integrating AI and the challenge of replicating AI solutions in different manufacturing environments present a major challenge. (9)

Solution: As the financial decisions can have serious consequences, cost-benefit analyses to describe future expenses and select AI solutions that can be expanded and provide significant returns on investment. (9,10) The total cost can be decreased, and scalability can be enhanced by making use of economies of scale and using modular AI solutions.

Regulatory and Compliance Challenges:

Challenge: Living up to today's strict legal demands poses some difficulties in manufacturing when progressing with new AI technologies on the grounds of privacy, safety, and quality. Author states, (9,12) *"Manufacturing companies are reluctant to share their data, because of their proprietary nature reducing the potential for supplementing the data through additional resources."*

"Some of the factors that contribute to this slow adoption of AI technology include issues with the economy of scale."

Solution: Applying effective regulatory strategies to inform users and practitioners in advance on the legal frameworks that govern artificial intelligence solutions. (9, 12) It is possible to implement systems that include AI explicitly designed to handle compliance and reporting.

Cultural and Organizational Resistance:

Challenge: AI implementation may be slowed down because of internal opposition, which may come from concerns of losing a job or changes to the usual working processes. (9,13)

Solution: Using organizational change management approaches to tackle culture by sending notices and messages, training employees on AI applications, and showcasing the effectiveness of AI to reduce mistrust. (9,13)

Intersectoral Collaboration:

Challenge: The limited interaction between academic institutions, industrial establishments, and government agencies hampers the development and adoption of AI solutions in manufacturing processes. Autor states, *"Improved Coordination among universities, industries, and government agencies can facilitate greater opportunities to push the field forward"*

Solution: Seeking collaboration between these sectors in a way that will capitalize on their specialty; industry experiences, research capacity, and governmental support. (9)

2.2 Smart Manufacturing- (Industry-4.0)

The paper titled "Smart Manufacturing Technologies in Industry-4. 0" gives an analysis of adopting new technologies to subsectors of manufacturing industries with the view of transforming manual manufacturing processes into intelligent environments.

Maheswari and Brintha discuss management of manufacturing with the integration of advanced digital technological applications. The authors describe how IoT, AI and big data are critical in changing the features of the traditional manufacturing contexts. They describe how these technologies increase productivity, help to produce

better products, and manage the degree of customization. More particularly, authors consider cyber physical systems and augmented reality to enhance the interaction between digital systems and human operators to minimize equipment breakdowns and product defects. They also find in their literature review a clear trend of digital transition within manufacturing that is supported by new smart technologies, which not only respond to issues characterizing today's manufacture industry, but also push the industry towards the direction of sustainability and efficiency improvement. The authors' discussion highlights a fundamental shift in industrial capabilities, which is also apparent in the shift from intelligent systems in manufacturing industries in Industry 4. 0.

The paper also discusses some of the problems that arise when implementing these technologies for example, the failure of some equipment during manufacturing, and suggests how such problems could be addressed with for instance through intelligent systems that could be used to predict such problems and then deal with them appropriately to make the manufacturing process safer and more efficient. Below are some of the major concerns and corresponding measures regarding the deployment of AI and automation technologies in manufacturing facilities:

Primary Challenges:

Lack of Data Availability: Machine Learning (ML) applications involve the use of large data sets to train the machines and it has been a challenge for the industry to get quality, relevant data. Because their dataset is not large enough, it is not suitable for their machine learning methods, since they have to work with large amounts of data in the smart manufacturing process. (18,20)

Data Utilization Issues: Despite information availability, there is a challenge on how best to get and apply such information in manufacturing because the sources and types of data can be many and complex. (18)

Technological Integration: Authors explore the role of IoT and AI in manufacturing and the possibilities of their integration. They stress how these technologies enable improvements in product design, manufacturing, and delivery of target end-products which are highlighted by digital changes.

Challenges in Traditional Manufacturing: The paper also notes several difficulties associated with traditional manufacturing systems, such as equipment failures, downtime, and imperfect product deliveries. These issues show why we must adopt smart manufacturing solutions to improve reliability and productivity.

Relationship Modeling: Statistical and machine learning methods are great at finding correlations, but developing dependency between variables can reveal how smart manufacturing should be improved. (18)

Worker-Specific Risk Analysis: To advance health and safety in workplaces, it is essential to establish how mental and physical demands overwhelm employees. (18)

Addressing the Challenges:

Industrial Internet of Things (IIoT): Applications of IoT improve monitoring of equipment in manufacturing facilities in real-time, improve scales of automation, and assist in maintaining quality besides decreasing the time of equipment breakdown. Author states, (18,25) *"Today even a simple cost effective IoT device can collect several variables regularly and send the information through the air almost in real time. These attributes are incredibly beneficial to any organization that aims at solving the problems*

facing them as they work hard to achieve increased productivity at a reduced cost and efficiently optimized production line."

Autonomous Robots: They are used to perform activities that are too risky or harmful to human beings, enhance product quality, safety, and productivity. Manufacturing autonomous robots also known as industrial robots are employed to optimize and automate repetitive work automatically with emphasis on minimizing human mistakes and to facilitate the relocation of workers in the operational sectors of production in industries.

Utilization of AI and Machine Learning: The authors state that by integrating and applying artificial intelligence and machine learning technologies, decision-making processes can be enhanced for managing such operations and tasks can be automated. AI can thus apply in maintenance, quality control and even in supply chain management meaning that it reduces costs and increases product quality.

Leveraging Big Data Analytics: For the problems that refer to the inefficiencies and downtimes, the paper proposes to apply big data analytics. It allows manufacturers to study large amounts of data collected during operations with the aim of discovering various trends, signs of possible developments, and methods of enhancing efficiency.

Cognitive Systems: Integration of sensor data with AI features such as ML and deep learning helps in improving manufacturing productivity through real-time data and insights. (18,20)

Virtual Reality (VR) and Augmented Reality (AR): It is used for safety training, as a predictive tool and to help enhance the different processes of production through digital modelling of its physical environment to increase real world interaction. (18)

Cognitive manufacturing: It is more efficient compared to traditional manufacturing processes and relatively very powerful. It is the use of information from the sensors that have artificial intelligence such as machine learning, deep learning and other AI to look for the model in the structured and unstructured data from the industry. (18,22)

2.3 Industry-5.0

The paper Artificial Intelligence from Industry 5.0 Perspective: "Threats and Challenges" addresses the problems associated with the adoption of AI in the context of manufacturing, with regards to the transition to Industry 5. 0 revolution.

Trunina, Bilyk, and Yakovenko explain the use of artificial intelligence (AI) in Industry 5.0, and this also supports the increased application of human-oriented and environment-friendly production technologies. The authors also note that AI and the adoption of machine learning enhance operational efficiency to achieve large scale customization at optimal cost. But they also respond to other important questions that AI raises, such as job automation, reinforcement of bias in machine learning, security issues. Also, they describe how the European Union promotes the use of AI technologies in innovation, implementation of the industrial revolution, etc., and propose that this approach may be useful in rebuilding the Ukrainian economy after a conflict.(26) The paper provides a detailed analysis of the necessity of ethical frameworks and the establishment of proper legal measures to prevent the negative consequences of AI implementation in Industry 5.0, ensuring its capabilities are securely used for the benefit of society.

Human-Centric Manufacturing: Industry 5. 0 underlines the cooperation between humans and machines, stressing the need for integration of human intelligence with new

technologies aimed towards higher levels of flexibility, productivity, and sustainability in production. (26,36) Author writes, “Artificial Intelligence represents an exciting frontier for Industry 5.0, but it also poses new threats and challenges.”

Challenges and Threats:

Job Displacement: The application of the AI technologies in manufacturing might result in changes in employment as more routines are likely to be automated. (26,30)

Algorithmic Bias: It seems that AI currently or in the future reinforces such biases or creates new forms of bias, hence having an impact on fairness and equality in workplaces and products produced. (26,30)

Cyber-attacks: The advancement of artificial intelligence can be utilized for the invention of new styles of cyber-attacks and techniques to modify security systems without being detected. (26) Violation of privacy, virtualization can become tools for gaining advantages by cybercriminals, resulting in losses for states and corporations and the population.

Lack of Legislative Framework: The authors discuss the lack of proper legal instruments to govern the deployment and growth of AI applications. This represents a challenge because there is currently no regulation of AI, and this means that AI systems with inadequate measures against possible harm could be developed.

Integration of AI with Human Workers: The need to ensure that artificial intelligence technology is incorporated in organizations in a manner that will help increase productivity while also ensuring that employees are satisfied, safe and retained is highlighted. (26,28) Thus, recognizing and maintaining a balance between the

proportions of automation and human interactions represents the key to success of Industry 5. 0.

Cultural and Organizational Adaptation: Managing organizational culture to fit the AI change is a challenge. Practical challenges include the fact that these changes must be managed to support organizational strategy; employees may complain about technological advancements that are advancing too quickly. (26)

Addressing the Challenges

Ethical Frameworks and Guidelines: To address the problem of negative consequences, it is essential to establish practical guidelines for the use of artificial intelligence. (26,29) This comprises the acceptance of the likely unethical effects of AI technologies and formulating code of ethics for its proper development and utilization.

Legislative Measures: The paper underscores the importance of strong legal frameworks to govern the application of AI solutions. It is possible to create proper regulations, which will help to avoid various abuses and improper usage of AI, and its further evolution will be safe and useful.

Human-Centric Approaches: To overcome the problem of job loss and at the same time keep humans at the heart of Industry 5. 0, the authors recommend the use of human centric approaches in manufacturing systems. This is a process through which AI is incorporated into the work environment without the intention of replacing human labor, but to support it in such a way that makes human labor more fulfilling. (26,32)

Security Protocols: The paper has proposed various measures to deal with security threats in the AI environment such as the integration of strict security measures and

systems. Improving cybersecurity can mitigate risks of cyber threats in the manufacturing facilities to maintain manufacturing reliability and security.

Transparency and Accountability: The authors provide recommendations that include increasing transparency and accountability in the creation of artificial intelligence. This can be done by ensuring AI decision-making is more transparent so that people can understand it hence increasing their trust and adherence to the use of AI.

Collaboration for Innovation: It suggests that the advancement of cooperation between the European Union, business entities, and educational institutions can promote the ethical application of AI. (26)

Strategic Approaches

Digital Transformation and Sustainability: (26, 35) This new generation is Industry 5.0 is not only designed to improve industrial processes through digitization, but it has to make sure these enhancements will lead to the sustainability of a green manufacturing environment.

Skills Development and Workforce Adaptation: When AI transforms industries new generation of employees needs to be trained to adapt to new technological trends (26, 36) hence upskilling and reskilling of the workforce is critical to enable organizations manage AI integration effectively.

2.4 Current Gaps in the Research

Nevertheless, many problems arise from the integration of AI and automation in manufacturing processes. Challenges include technical challenges in adopting new systems to the existing systems in an organization, and financial challenges such as huge investment costs. Furthermore, the skill gap within the workforce remains high, while

important ethical issues, such as job replacement, bias of algorithms, and security issues, are also present. (1,9,18) These concerns are both complex and need to be discussed in detail, covering challenges and their possible solutions.

Review of this literature will seek to explore the crucial issues that revolve around the implementation of AI and automation technologies within the manufacturing industry. It aims to identify new ideas and effective measures which have been suggested to address these issues to make the transition to Industry 4. 0 and beyond. The review concentrates more on the technical, financial, workforce, and ethical perspectives of this integration and provides ideas on how these challenges can be addressed.

This review focuses on analyzing the AI and automation technologies as applied within manufacturing industries that are moving from Industry 4. 0 to Industry 5. 0. It covers multiple technologies like robotics, big data analytics, IoT, and cognitive systems in multiple manufacturing industries. The review includes academic papers, industry reports, and case studies to provide a broad perspective of the current state of AI and automation in manufacturing.

The works that were relevant to the study were obtained through searches in freely available databases like IEEE Xplore, Science Direct, Google Scholar among others. These keywords include Artificial Intelligence in Manufacturing, Automation Challenges Industry 4.0, and Solutions for AI Implementation in Industry 5.0. In addition, a manual search was conducted to confirm the reference list of the identified key resources to gather a wide range of sources.

The selection criteria included the connection of the work to the broader theme of the study, which centered on artificial intelligence and automation in manufacturing, the

quality of the studies, ages of the publications within the last ten years. The best collection of this material should be based only on empirical and theoretical research papers. The top-ranked papers are those that offer a clear understanding of the problem and offer realistic solutions. Excluded from the criteria were papers that did not have manufacturing as a main subject.

CHAPTER 3

METHODOLOGY

The research methodology employed in this study utilizes the Interview Protocol Refinement (IPR) Framework, which is a thorough and systematic strategy aimed at improving the reliability and performance of interview protocols in qualitative research. (37) Using the IPR technique, I performed formal research interviews and gathered qualitative data from responses provided by multiple prominent manufacturing companies. This methodology permitted an in-depth analysis of industry-specific knowledge and methods, thereby enhancing the study with a wide range of viewpoints and extensive empirical data. This section provides a comprehensive explanation of each stage of the IPR framework, specifically focusing on the methods and strategies employed to create, improve, and execute the interview protocols that closely correspond to the main research inquiries. (37,39) The careful implementation of this framework guarantees that the gathered data is not only comprehensive and challenging but also specifically relevant to the research goals.

The interview protocol framework is comprised of four-phases as shown in

Table 1.

Table 1: Phases of the Interview Protocol Refinement (IPR) Framework
Phase Number Phase Name

Phase 1	Ensuring interview questions align with research questions
Phase 2	Constructing an Inquiry-Based Conversation
Phase 3	Receiving Feedback on Interview Protocols
Phase 4	Piloting the Interview Protocol

3.1 Alignment Between Interview and Research Questions

The initial stage of the IPR framework involves an organized process of aligning the interview questions with the research topics. The alignment is essential since it implies that each interview question is calculated and directly states to the exploration of the research topics.

Initial interview questions are created based on the research questions. The purpose of these questions is to be open-ended in order to stimulate comprehensive and detailed responses from industry professionals. This will help us gather data with greater depth and context. (37)

An alignment matrix works as a tool to correlate each interview question with particular research topics. It helps to quickly view how much each of the research questions is addressed, and in the identification of areas that might require further investigation. Each question can be evaluated optimally by obtaining detailed information relevant to the research questions. (37,40)

After a matrix analysis, the interview questions are carefully analyzed and modified to ensure they are more closely aligned with the research objectives. This may involve rephrasing questions, combining, or dividing them, or eliminating those that do not directly contribute to the research objectives. (37) This iterative process ensures precision in the questions, which in turn enhances the effectiveness of the data collection.

3.2 Constructing an Inquiry-Based Conversation

The second phase focuses primarily on refining the interviewing process to optimize an efficient and seamless connection. However, it is crucial that it provides the greatest possible assistance to the investigation. This stage is essential because it involves the need to find a balance between gathering extensive data and creating a comfortable and appealing environment for the interview participants.

A detailed script is prepared that gives a clear idea to the interviewer about how to start the study, how to transition between topics, how to ask difficult questions, and how to end the interview. The script includes not only the questions but also potential probes and follow-up questions if more depth is needed on a particular topic. (37)

The interview structure is purposefully meant to follow the natural flow of a conversation. At the start of the interview, questions that are easier and less threatening would ensure to initiate the process of relationship development, thereby working in, in the course of the interview, harder or perhaps more challenging lines of questioning. Transition questions are also carefully cast to minimize distraction during the shift from one subject to another while maintaining the conversational tone of the interview. (37,39)

To ensure thorough understanding and clarification, a set of probing questions and follow-up questions are prepared in advance. (37) These probes encourage the participants to give a more descriptive explanation about the topic or to explore some elements that were not initially investigated to improve the information that will be recorded. will be recorded.

Table 2: Example of Interview Protocol Matrix

	Background Information	Research Question 1	Research Question 2	Research Question 3
Interview Q 1	X			
Interview Q 2	X			
Interview Q 3		X		
Interview Q 4		X	X	
Interview Q 5			X	
Interview Q 6			X	X
Interview Q 7				X
Interview Q 8		X	X	X
Interview Q 9	X			
Interview Q 10	X			

(Table 2, Castillo-Montoya, 2016)

Structuring these questions effectively not only provides a smooth and natural conversation but also ensures that the interview fulfills its purpose of gathering relevant data. There are four primary types of questions used in research interviews: 1) Introductory questions, 2) transition questions, 3) key questions, and 4) closing questions. (37) Each type has its function and helps to direct the interview from the first welcome step to an effective outcome. Here's how each type contributes to the overall interview process:

Table 3: Types of Interview Questions

Type of Question	**Explanation of Type of Question**	**Example of Type of Question**
Introductory Questions	Questions that are relatively neutral eliciting general and non-intrusive information and that are not threatening	Based on the information that you provided in the questionnaire; you went to high school at _____. Did you grow up in _____? If yes: Go to question #2 If no: Where did you grow up? (see question 1 in Table 1)
Transition Questions	Questions that that link the introductory questions to the key questions to be asked	In your questionnaire, you said that your ___ (mother, father, or guardian) had a ___education. Is that correct? If says yes: Does that mean that you are the first in your family to enroll in college? If says no: Who else in your family has gone to college?
Key Questions	Questions that are most related to the research questions and purpose of the study	What makes you identify with that community?
Closing Questions	Questions that are easy to answer and provide opportunity for closure	Before we conclude this interview, is there something about your experience in this college/university that you think influences how you engage in your classes that we have not yet had a chance to discuss?

(Table 3, Castillo-Montoya, 2016)

3.3 Receiving Feedback on Interview Protocols

During the third stage, the interview schedule is extensively tested and refined based on feedback from peers and from sample participants. (37) Feedback is important in ensuring that the questions are clear, accurate, and effective.

The first level is peer review and review by my leading professor, an expert in qualitative research methods. The purpose of such a peer review process is to seek ambiguities, biases, or further improvements in the interview questions through the protocol or the overall structure of the interview. (37)

Think-aloud sessions are held with participants who show similar characteristics to the predefined target group of the study. The participants must say out loud the thought

processes that are going on in their heads as they answer the questions. This feedback indicates potential areas of uncertainty or misunderstanding in the questions, allowing for further improvement of the process. (37,42)

The interview protocol was carried out by reading each question aloud to replicate the actual interview environment. This enabled the researcher to determine the foundational consistency and clarity of each question.

I wrote down 'Yes' or 'No' for each item to show whether the item met the criteria in the checklist. The criteria regarded such elements as whether questions were straightforward, matched the research questions, and could provoke comprehensive responses.

I gave detailed content about questions that are marked 'No' for elaborations and suggestions of improvement to create clarity, relevance, and engagement of the question. Table 4 shows the feedback given:

Table 4: Activity Checklist for Close Reading of Interview Protocol

(Table 4, Castillo-Montoya, 2016)

Aspects of an Interview Protocol	**Yes**	**No**	**Feedback for Improvement**
Interview Protocol Structure	●		
Beginning questions are factual in nature	●		
Key questions are majority of the questions and are placed between beginning and ending questions	●		
Questions at the end of interview protocol are reflective and provide participant an opportunity to share closing comments	●		
A brief script throughout the interview protocol provides smooth transitions between topic areas	●		
Interviewer closes with expressed gratitude and any intents tostay connected or follow up	●		
Overall, interview is organized to promote conversational flow	●		
Writing of Interview Questions & Statements			
Questions/statements are free from spelling error(s)	●		
Only one question is asked at a time	●		
Most questions ask participants to describe experiences andfeelings	●		
Questions are mostly open ended	●		
Questions are written in a non-judgmental manner	●		
Length of Interview Protocol			
All questions are needed		●	Considering the allotted time and interview duration, the focus was placed on key questions.
Questions/statements are concise	●		
Comprehension			
Questions/statements are devoid of academic language	●		
Questions/statements are easy to understand	●		

Instead, before the collection of the actual data, the pilot procedure of the interview methodology is done with a small number of participants who are within the

target population of the study. (42) The pilot is carried out under conditions that almost simulate the actual interview environment.

Pilot interviews are carried out to assess the practical implementation of the interview technique. This involves evaluating the progression of the interview, the suitability of the questions, and the total length of the interview.

The observations made during the pilot interviews are utilized to make necessary refinements to the interview process. This may entail rearranging inquiries, modifying the phrasing for enhanced lucidity or influence, and refining the script to align more effectively with the interview setting. (37)

3.4 Research Questions:

I have carefully developed questions for interviewing various manufacturing organizations using the Interview Protocol Refinement (IPR) technique. These questions are set in an organized framework comprising several specific types of inquiries. To the furthest extent possible, application of these questions will be taken to ensure that there is a comprehensive understanding concerning the topics that are relevant to our study. They are organized as follows: (37)

- introductory questions, which are designed to ease participants into the conversation and establish a comfortable dialogue environment.
- transition questions, to smoothly shift the conversation toward more significant topics.
- key questions, which are the main focus of the interview aimed at extracting detailed and substantive insights relevant to the research objectives.

- closing questions, intended to conclude the interview on a reflective note, allowing industry leaders to add any final thoughts and summarize their perspectives.

Below are some standard questions combined including with specific research questions that I have developed to use appropriately during the research interviews. Each was designed to get a relevant and meaningful response from the respondents.

Introductory questions included:

1. can you please share a bit information about the educational and professional path that led you to your current role?
2. Did your formal education directly involve AI, or did your interest develop through other experiences?
3. How has your corporation encountered or incorporated AI into their practices?
4. What were some of the key factors or business needs that drove your decision to start implementing AI solutions?

Transition questions included:

5. Can you tell me a bit about some of the common ways your company is using AI technology?
6. What are some of the ones your company finds most useful?
7. Has AI implementation had a significant impact on your company's productivity, efficiency, or competitive edge? If possible, can you please share an example?

The research questions included:

8. How could you describe the industry's current perception of the state of AI technology? (and what contributing factors shape this perception)?
9. What are the primary factors that influence the industry’s adoption and implementation of AI technology? (within your organization) (like cost, trust, ethical, ROI etc.)
10. How does industry operationalize those mentioned factors? (on a scale)
11. Follow-up questions included:
12. What are some of the key challenges your company faces when scaling your AI capabilities or implementing AI technologies?
13. Do you think these factors might vary depending on the specific industry or sector a company operates in?
14. How is your company working to overcome these challenges?

Closing questions used to wrap up the discussion included:

15. Are there any emerging AI technologies or trends that your company is particularly excited about or concerned about exploring in the future?
16. What skills do you believe are essential for students/professionals working on AI projects within your company?
17. Before we conclude this interview, is there anything else you think is important to share about AI’s role in your organization or industry?

I conducted formal research interviews and gathered qualitative data by applying the Interview Protocol Refinement (IPR) methodology in leading businesses in different manufacturing sectors. Applying the IPR approach at every stage in developing and refining interview protocols is rigorous. It therefore ensures that the methodological

soundness and richness of interview-derived qualitative data directly address my research questions. This intensive planning and careful editing approach proved helpful in enriching the scholarly contributions of the study in terms of the truthfulness and trustworthiness of the research findings. Owing to such a systematic process, the research data so generated carry valid fresh insights that contribute to a better understanding of the manufacturing sector, thereby confirming the effectiveness of the IPR framework in inducing quality research outcomes.

CHAPTER 4

ANALYSIS

The data analysis section of my thesis is based on structured interviews conducted with representatives from three companies: Company 1, Company 2, and Company 3. The analysis aims to uncover themes and patterns related to the adoption and impact of AI technologies within these companies. Here's how the qualitative data from the interviews can be analyzed:

Thematic analysis is a method used in qualitative research that involves identifying, analyzing, and reporting patterns (themes) within data. It organizes and describes the dataset in detail and interprets various aspects of the research topic. Thematic analysis is widely used because it provides a flexible and useful research tool that can yield a rich and detailed, yet complex account of data.

4.1 Thematic Analysis Process

Data Preparation: Read through all interview transcripts carefully to get a good grasp of the content. This step helps you become familiar with the depth and details of the data.

Initial Coding: Go through the interview transcripts line by line to identify important pieces of information. Assign a short label or code to these pieces that summarize the essence of what is being said. This step helps in organizing the data by breaking it down into manageable segments. For example, coding might involve tagging a sentence where someone discusses AI improving efficiency as "efficiency enhancement." (46)

Categorizing Codes into Themes: Look for patterns among the codes that relate to each other and group these codes into potential themes. A theme might gather all data related to how AI is changing business practices, for instance. (46)

Reviewing Themes: Check if the themes make sense in relation to the coded extracts and the entire dataset. This might require you to merge some themes, split others into sub-themes, or discard themes that don't have enough evidence supporting them. This refining process ensures that the themes accurately reflect the collected data. (46)

Defining and Naming Themes: Clearly define what each theme is about and give each one a concise name that captures its essence. This involves describing how each theme relates to your research questions and why it is significant. This step helps clarify what each theme covers, making it easier to understand the broader implications of your findings. (46)

By following these steps, I was able to conduct a thorough and systematic analysis of the qualitative data, leading to insightful conclusions supported by clearly defined themes derived from the interviews. This methodical approach helped in understanding and presenting the complex dynamics of AI integration within the companies studied.

Derived Themes

This section highlights the nine major themes and their significant impact on the companies that illustrates real-world scenarios as follows:

4.2 Business Needs

Codes: "Technological integration", "solving complex problems", “competitive edge”

Quotes that Illustrate themes:

Company 1: “stay competitive and we see AI as a tool that would allow us to really improve the performance of our product.”

Company 2: “But a lot of them are super technical, so we have a lot that involve complex simulation.”

“We’re doing a little bit of work on how you start building data sets across factories.”

Company 3: "Our primary competency is high performance computing and the software needed to solve these large-scale, very complex engineering problems."

Description: This theme discusses the basic and primary purposes for organizations to adopt AI technologies. The adoption of AI systems is recognized as an essential factor for maintaining competitiveness, enhancing existing processes, and solving certain problems in industries. Applying the AI system is important for Company 1 to address market pressure and improve the effectiveness of products for the company to remain competitive. At Company 2, AI assists in complex simulations and the integration of various data across multiple factories, which is essential for optimizing manufacturing processes and improving data management, these are key factors for operational efficiency. Company 3 utilizes AI in high-performance computing to solve complex engineering issues that exceed the capabilities of traditional computing methods.

4.3 Innovation

Codes: "product integration", "data processing and analyzing", "operational efficiency"

Quotes that Illustrate themes:

Company 1: “This project that we're working on with the water jet is to my knowledge the first AI project.”

“It's more like people are starting to think about it, but they're not really.”

Company 2: “what comes off the production line being able to question and query that and start to understand the data sets and little better, that's where we've seen a good amount of value.”

Company 3: “We tend to train some sort of machine learning algorithm to essentially leverage the database."

“Something faster running like an engineering tool or an assessment tool.”

Description: This theme focuses more on how AI is being used as an enabler within companies to create new competencies or improve upon existing ones. For instance, Company 1 has started an AI project to improve water jet technology, which is a form of digital manufacturing. This is new and unique in an industry where the concept of AI may not have been implemented previously. Company 2 applies the concept of AI in the enhancement of data handling on production lines as a way of enhancing data processing and performance of the company through better insight on production lines. Company 3 has also adopted the use of machine learning algorithms to maximize the use of databases and improve the effectiveness of the engineering tools making it work better and solve complex issues more effectively than human input.

4.4 Current Perception

Codes: "mixed optimism", “Influence”, "skepticism", "slow adoption".

Quotes that Illustrate themes:

Company 1: “I think it's really early stages.”

“Read on news, trying to see how and make use of it.”

“I suspect that most companies are kind of where we are.”

Company 2: "It's interesting but, probably still a little skeptical."

“When you start thinking about small medium sized businesses, whether it be like a small machine shop or something, again it is very slow to adapt to technology.”

Company 3: "Skeptical, the fact that you just don't make mistakes, you want to understand the methodology you're using."

Description: This theme explores the general views towards AI within companies like Company 1, Company 2 and Company 3, as well as across their industries, which shows a mix of cautious optimism and skepticism. Almost all these companies are in the early stages of adopting AI into their operations, with their AI beliefs shaped by external sources such as media coverage and what they read or hear about AI, indicating that they are still exploring and trying to understand AI and the risks or opportunities it brings. Company 2 and Company 3 remain cautious about the reliability of AI solutions, which can be viewed as a wise approach to AI adoption and its consequences. However, Company 2 also identifies the low rate of AI adoption by small businesses, which is a

larger industry issue as smaller organizations may be unable to effectively implement or utilize AI.

4.5 Adaptation and Implementation

Codes: "Enhancing product features", "user experience", "Data-Driven outputs".

Quotes that Illustrate themes:

Company 1: “I think ChatGPT got people's attention and stoke their admin imagination.”

“We are now attempting to do with AI, finding the keel, finding the rib meat and that experience just sort of led me to believe that we had kind of reached.”

Company 2: “We've started to put it into our products and very much there from a UI UX experience."

Company 3: “PhDs who can create complex solutions based on analytical data and fundamental theories. This allows for thorough verification and validation from the ground up, building confidence in the solutions.”

“We'll give a set of inputs, it will learn that database to give the outputs the customer needs, whether that customer wants outputs to be.”

Description: This theme focuses on how several companies are using AI in their operations and ways of enhancing their products. Company 1 uses AI to enhance specific features of their products, showing a focused approach to AI for targeted feature enhancements. Company 2 employs AI to improve the overall user experience, indicating a great application of AI in product development. They state that they employ AI in a slow and cautious manner, suggesting that they have thought about it for quite some time. Company 3 has a technical approach to Artificial Intelligence where highly qualified

personnel are involved in designing and deploying AI to enhance efficiency and reliability of the systems it deals with. They employ AI to deal with large amounts of data and to provide custom results which makes their solutions more accurate and applicable.

4.6 Challenges

Codes: "Data requirements/management", “Workforce concerns", “High operational costs"

Quotes that Illustrate themes:

Company 1: “Variations in meat to recognize features, how many training images do we need?”

“Using C++, if necessary, like that would be more like a minor sort of hiccup that might cost us a little time.”

Company 2: “When you're trying to innovate on the technology, especially if it's not your core competency, which it isn't for manufacturers trying to get the right use case is challenging sometimes for them.”

“I'm working through the relevant workers, Council unions, labor laws, that becomes quite challenging because, again, then they have concerns. It's going to eliminate jobs.”

Company 3: "The significant costs are more associated with using simulations from a supercomputing high-performance computing (HPC) cluster."

“These costs are substantially higher than the training costs for models and are seen as the primary limit to scalability.”

Description: This theme highlights the different barriers that organizations experience during the implementation of AI solutions. Some of these include mainly technical and data issues comprised by the problem of getting enough suitable training

data, and further small technical changes which can significantly take time to implement. Company 1 has issues such as technical integration of the system and the fact that AI requires a lot of data for its training particularly for companies like Company 2 which is not primarily operating within the field of artificial intelligence. It can also lead to a poor understanding of which applications are feasible, thus blocking integration. Workforce resistance is another major challenge, including concern that AI may replace people and lead to opposition from workers and trade unions, which also influences the time required in AI deployment and acceptance in the organization. Last, but not least, the financial limitations, where Company 3 pointed out, highlight the fact that high-level AI applications often require considerable computational power.

4.7 Hesitancy

Codes: “Transparency”, "ROI concerns", "ethical concerns", "trust in AI outcomes".

Quotes:

Company 1: “I think we could use AI, but you need to start somewhere, and this seems like a good place to start.”

Company 2: “So don't tend to be particularly quick to establish new technology, because for them they're not going to build up a team of developers to be worth when they want to buy something off the shelf.”

“We’ve seen some progress, but it's been pretty slow.”

Company 3: “Balancing costs with the need for trustworthy and effective solutions is crucial in managing resources efficiently.”

“So, there's excitement, but there is still a lot of verification and validation that has to go into building that confidence at this stage.”

Description: This theme involves the various ways in which corporations approach AI adoption and how they are skeptical about it. Company 1 recognizes that AI has to be implemented somewhere and this speaks of a realistic approach towards the issue of hesitance through gradual adoption of AI. Company 2 notes that there is a common phenomenon in the industry where slow adaptation rates are associated with economic and practical issues, especially among smaller companies that cannot afford good resources and to experiment with new technologies. company 3 strongly suggests the importance of thorough verification and validation before fully implementing AI, showing a common sentiment across many industries.

4.8 Trust Issues

Codes: "Data security", "operational reliability", "Decision making".

Quotes that Illustrate themes:

Company 1: “Not concerns on ethics, we're not like a company that makes security equipment to be installed in public places.”

Company 2: “Trust- certainly an area that people get quite concerned about, protecting some of those pieces and some of those manufacturing secrets, that's certainly an area that people would be concerned about “

Company 3: "Trust is a significant factor in decision-making regarding the methods to be used."

“When I say here's a black box that gives you an answer that doesn't necessarily give you a good feeling. So that's really, it's skeptical.”

Description: This theme focuses on the trust associated with AI and its application and adoption in the business environment. It focuses on companies' concerns about how AI systems manage sensitive data, make decisions, and the transparency of these

processes. There is less focus on ethical issues in Company 1 because the company does not face heavy privacy or security threats in its line of business. But this is not the same for all industries, especially as evidenced by Company 2 and Company 3. Company 2 reports concern trust relating to issues of intellectual property and personal data and hence need AI system to be assured to manage sensitive data. Company 3 expresses some of the issues about the decision-making process and that some AI systems work in a black box, so their operation is not fully understood.

4.9 Understanding

Codes: "Required training", "Economical benefits", "Simplicity and explainable AI".

Quotes that Illustrate themes:

Company 1: "I'm sure there's things that we haven't thought of that, we're goanna learn along the way."

Company 2: "They probably don't have that degree of background, so being able to access the information and start to question and query the models without that level of technical background, certainly a place that we've seen."

"The way I see it is, it keeps jobs in that place because it potentially makes locations that are not as economical a lot more economical."

Company 3: "You must have some sort of level of competency in order to actually get a good solution out of that software."

"There's a strong inclination towards using methods that are simpler and more explainable to stakeholders, which in turn builds confidence and trust among users and customers."

Description: This theme sums up how knowledge, skill and accessibility are necessary to adopt and apply AI in organizations. It follows the companies' awareness of

the fact that AI implementation requires technical knowledge and constant training. According to Company 1, the use of AI is not only about technological deployment but a continuous process of training and optimization. Company 2 seeks to make AI easily understandable and accessible by the general public hence underlining the need to develop friendly interfaces for widespread use of AI technology. Furthermore, Company 2 has a clear and positive vision of AI as a tool for economic development, referring to its impact on the change of both businesses and the general economy. Company 3 points to the fact that it is necessary to have the correct skills and use less complex, more transparent AI techniques.

4.10 Future Directions

Codes: "Emerging technology", "Expanding applications", "Increasing automation"

Quotes that Illustrate themes:

Company 1: "AI has potential in every area"

"Using AI to help troubleshoot and maintain the machines is another example, but then also in our organizations just sort of overall kind of business flow."

Company 2: "Generative AI is definitely high on the list and then you start to look at how you can embed it with virtual reality."

Company 3 "Large language models play a part in that."

"But do think it gives you ways to do things you couldn't do before or that you couldn't do without a lot of extra expertise."

Description: This theme highlights the positive and forward-thinking strategies of these companies for AI technology. All three companies agree with the idea that AI is not

only a method of improving present business processes but also a key to the development of future business and technologies. To Company 1, AI is crucial in every aspect of their operations, specifically in maintenance and business operations, so it shows that it has a wide-reaching role in company efficiency. Company 2 is especially keen on integrating AI with other advanced technologies such as virtual reality, which, if implemented in manufacturing or any other field, can significantly enhance real-life user experiences and efficiencies by leveraging AI. Company 3 look at large language models and similar fields to show how AI can take complex tasks that previously needed a lot of effort to execute and make them as simple possible, which shows how Company 3's strategy of using AI is aimed at making things simpler for people.

Below Figure1 gives the analysis and impact of codes on different companies with positive and negative connections with AI respectively.

- color indicates probability of same codes mentioned by most of the companies. (i.e. All 3 companies)
- color indicates probability of same codes mentioned by few companies. (i.e. 2 companies)
- color indicates probability of same codes mentioned by only 1 company.

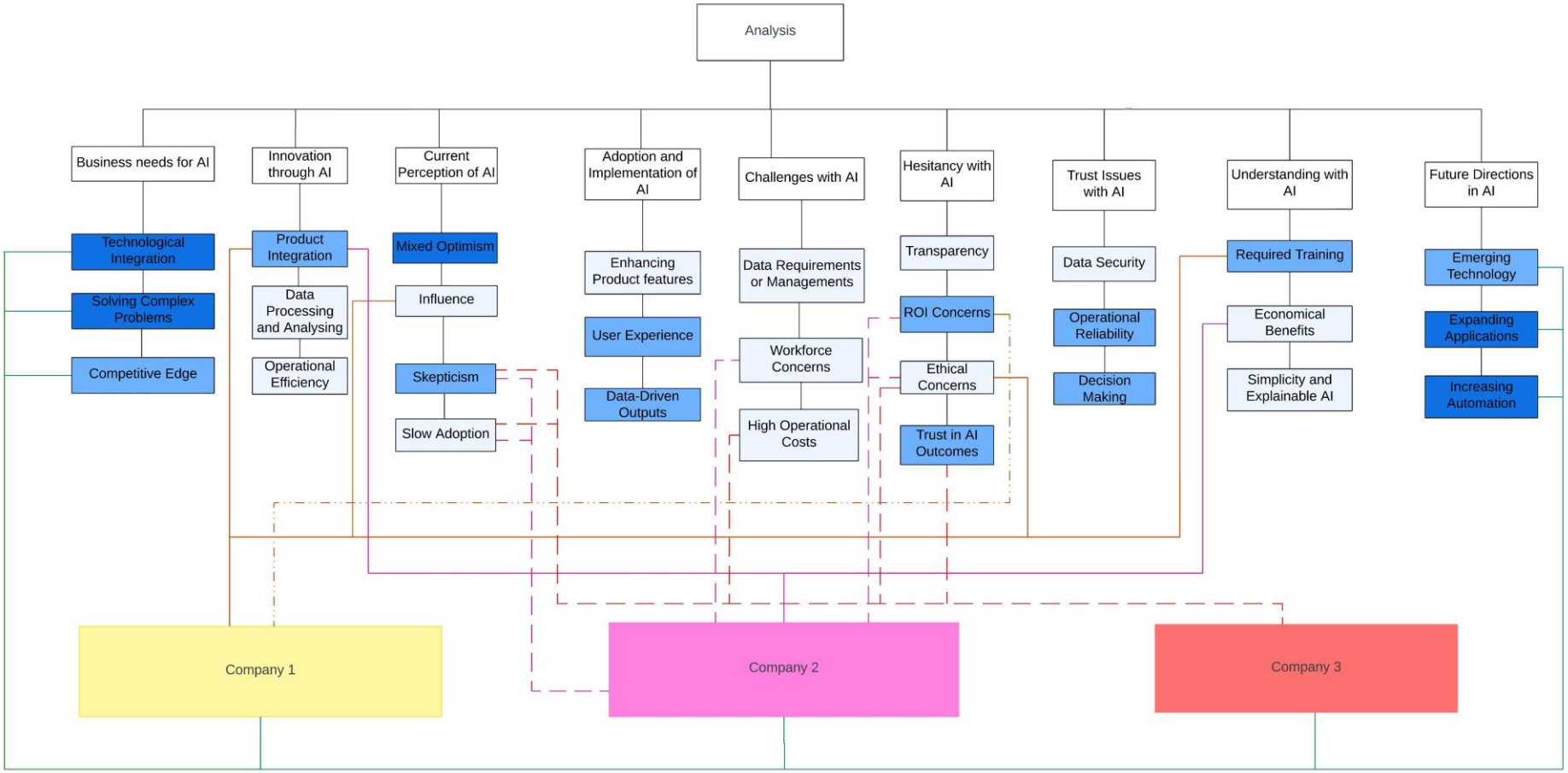

Figure 1: Themes and Codes Generated from Analysis

(____) Straight line indicates positive(+ve) impact on companies with AI

(_ _ _) Dashed line indicates negative(-ve) impact on companies with AI

(- - - -) Mini-dashed line indicates neutral impact on companies with AI

CHAPTER 5

RESULTS

The thematic analysis of structured interviews with representatives from Company 1, Company 2, and Company 3 has provided valuable insights into how these companies are using and being affected by AI technologies. The analysis identified nine key themes that help us understand the complex ways AI is being integrated in these industrial settings. These themes cover various aspects of AI adoption, from the reasons companies use AI to the future possibilities and concerns about trust.

5.1 Business Needs

The analysis shows that companies are using AI mainly for three reasons: to challenge competitors, solve various issues, and introduce innovative and advanced solutions and technologies. Company 1 implements AI because it aims at enhancing their products in order to meet the market trends. In a similar manner, Company 2 employs AI in activities such as handling and running complex simulations and data at various manufacturing plants to increase efficiency. Company 3 employs AI in high performance computing to solve complex engineering problems which cannot be solved easily. From this information, we can understand that AI is necessary for these companies as a core element rather than on a supplementary level. It directly deals with tackling daily problems, inspiring creativity and keeping ahead within such markets that rely closely on technological advancement. This analysis reveals how much AI is significant in

transforming the operations of companies and its significant role in the business strategies of organizations that utilize advanced technology.

5.2. Innovation

Companies are beginning to recognize AI as a booster not only enhancing current capabilities but also adding new ones. For instance, Company 1 is applying AI into conventional manufacturing industry enhancement where it is working on water jet with the aim of improving its efficiency and precision. This is a clear indication of a revolutionary set-up in how common manufacturing processes were previously managed. In the case of Company 2, the application of AI enhances the analysis of data from the production lines with much efficiency. This use of AI assists them to speed up their decision-making process since in manufacturing environments, prompt information is crucial in improving productivity and reducing costs. Additionally, Company 2 is also exploring how it can leverage AI for effective data management and utilization of data from multiple factory sites meaning that both companies have complete approaches in their manufacturing applications of digital technologies. Machine learning is used by Company 3 for enhancing the utility of engineering tools. These tools can perform simulations and analysis which cannot be handled using other conventional approaches. These examples prove that AI is not just about automating processes and making them faster, but about generating new opportunities and solutions that were not possible before. This not only enhances the quality of the engineering solutions given but also increases the efficiency of such processes. This innovation theme demonstrates how AI plays a pivotal role in large operational changes and skills that define new businesses. These companies are not employing AI only to make minor improvements but are implementing

it at all levels to stay relevant and to be on top of technological advancements within the market.

5.3 Current Perception

These perceptions highlight a dual nature in which companies have measured confidence and concern when it comes to employing AI. Their initial efforts in implementing the new technology are motivated by factors such as what they read in the media or what they find the other organizations are doing, which sometimes set a high expectation or focus on possible complications. Company 2 and Company 3 both have concerns over how accurate and established current AI technologies are. They highlight the need to plan carefully and test AI before implementing it completely. Company 2 notes that small size companies or start-ups are not implementing it because they have limited resources, lack of fundings, and lack of expertise or knowledge needed to implement it, showing a significant gap in how AI is being used across different sizes of businesses. Furthermore, the careful strategies of Company 2 and Company 3 in using AI also reveal a trend in industries where companies are interested in what AI offers them while simultaneously being conscious of issues arising from it. This balanced view ensures they are ready to use AI and improve their operations while being fully aware of what can go wrong if they continue with the AI projects without precautions. These features provide a clear picture in which AI is being implemented in business settings where potentially passion for the application of advanced technology has to be balanced with reason and metrics and business initiatives so as to ensure that the use of AI brings about positive results and not the creation of further negative impacts.

5.4 Adaptation and Implementation

Companies are carefully and strategically integrating AI to improve their products and the overall user experience. To a certain extent, Company 1 incorporates the use of AI by focusing on features of the products that can be improved to impact their quality significantly. Another Company 2 applies the use of AI in their technologies so that it is manageable by the general person in the society. This consists of enhancing the users' interfaces which will assist in making difficult systems more friendly to the users. Company 3's example of using AI is focused on utilizing the company's highly qualified staff, including PhDs, who can create unique solutions based on analytical data. This approach helps to guarantee that the developed AI solutions are effective, highly functional, and capable of bringing considerable operational benefits, including user-oriented outputs that increase customer interaction and service improvement. This analysis shows that the integration of AI is closely aligned with the company's specific business goals. Together, these examples highlight a commitment to using AI not just for minor improvements but as a key element of product innovation and operational excellence, designed to meet specific business needs and customer expectations. The focus on making AI tools more approachable shows a need for integrating AI into the business in a way that is both realistic and beneficial.

5.5 Challenges

There are several challenges associated with integrating AI into business operations or processes. These technical factors include managing large amounts of data, possible concerns from employees about job loss and security, and the high costs if they want to use advanced AI technologies, which can be expensive and significant challenge

for small-scale businesses. Company 1 has issues such as technical integration of the system and the fact that AI requires a lot of data for its training. Company 2 has noted some challenges in integrating AI innovation with their core operations in manufacturing. This misalignment can result into challenges in determining the relevant AI applications that will create value hence slowing down the AI adoption, integration process and the overall impacts of using AI towards optimized operations. Another challenge is that of workforce resistance; this was seen when Company 2 interacted with unions and laborers. Fears about job displacement due to AI are a major issue; they lead to major barriers, and seriously block the implementation of AI and require additional workforce training and more convincing in the change of management. Furthermore, Company 3 also reveals high costs for the AI solutions, which need extensive computing power, like simulation capabilities and data analysis. These costs can be very high, making the implementation of AI technologies difficult for most organizations. This shows some of the real-life issues companies come across when they decide to adopt AI. To overcome these challenges AI integration is a must, and it should be done systematically and at the same time taking care of the impact on the people.

5.6 Hesitancy

While companies recognize that AI has many positive aspects, they are careful not to apply it at once. Some of the factors include whether the particular investment in AI will generate the needed return on investment, ethical issues, and whether the technology is fully developed. Being cautious means companies do not rush to implement the use of artificial intelligence in their operations, they think carefully about the risks and benefits before deciding to use. Company 1 is first implementing small AI projects

and will expand if they perform well over time. This way, they can experience the effectiveness of employing AI without having to spend a significant amount at the beginning. This is a good strategy as it enables them to gain experience and adapt along the way. Currently, AI is not adopted actively by Company 2 because it is concerned with its high cost without significant returns. They look for AI that is efficient and that is able to achieve the greatest value for the resources they have to spend. Finally, company 3 stresses the importance of validation and verification before fully implementing it. On one hand, there are great opportunities in the case of AI and on the other; there are threats with regards to misapplication of the same. This includes careful and proper planning of the implementation of AI into the organization and ensuring that both AI and the organization is ready to adopt changes that AI brings. All together, these highlight how there is optimism about AI's potential to transform organizations cautiously, with a view of the challenges that may limit its success when implemented. This cautious approach helps make the integration process both effective and efficient, planning to achieve the greatest positive results with minimal negative impact.

5.7 Trust Issues

Trust is still an essential issue that defines the technological advancement of artificial intelligence. Issues of privacy, explainability, and AI decision-making, as well as operational robustness, are the major topics of concerns when it comes to AI adoption. Company 1 is not very much worried about ethical issues compared to Company 2 because of the type of business they are in though they clearly understand the importance of trust when it comes to privacy of information. Both Company 2 and Company 3 present major concerns regarding trust, especially on how data is handled by the AI

systems, and decision-making process. The fact that some AI processes are not fully explained, this is commonly explained as the black box problem whereby you cannot explain how the AI works. Due to this, the use of AI is not easily accepted by people since they cannot agree to what they do not understand. This is a general problem within the industry where developers are expected to design intelligent and systems that are not only intelligent and efficient but also explainable. This makes it very important for companies to make their AI solutions as interpretable as possible to avoid these issues of complexity. Addressing these trust issues is important since it affects everything, including the adoption of AI for strategic purposes and its acceptance among employees and other stakeholders. In addition to being effective, AI systems should function in a way that complies with societal norms and ethical requirements.

5.8 Understanding

It's important for companies to understand AI well to use it effectively. This means they need to keep learning and adapting as AI technology changes quickly. Company 1 realizes that using AI is dynamic and it is not a one-time process of setting up but rather a constant process of learning and enhancing. Company 2's approach is to make AI something that is available and usable by anyone, not professional programmers and computer scientists. They built AI systems that are basic and easy so that more people could use AI instead of feeling stressed. This approach also enables jobs to remain safe because AI can make things better without having to eliminate humans. Company 3 prefers transparent AI techniques or methods that can be easily explained. They presented their idea that people develop more trust in AI when they can observe the decision-making process of an AI model. This makes AI more effective because users

and customers know and feel that it is believable. This analysis seeks to make it clear that knowledge and skills enhancement are crucial in enabling organizations to implement artificial intelligence. Through education and training, the companies' ideal goal is to develop a skilled workforce capable of adopting AI and understand the impact of such technologies to tailor its implementation towards positive impacts, ensuring that AI technologies are used effectively and responsibly.

5.9 Future Directions

Furthermore, AI is seen by the companies as a significant factor for the development and innovation of industries. Company 1 believes AI will be crucial across all their business areas, especially in maintaining and troubleshooting equipment, which can help keep operations running smoothly. Company 2 is very enthusiastic about integrating artificial intelligence and virtual reality, which can transform interactions with the systems while boosting the general functionality of the technology. This approach not only makes AI more valuable but also enhances the potential of other technologies that can be connected. Company 3 are curious to explore large language models and their ability to automate tasks that normally would take much effort to do. Such models can perform various complicated tasks that can enable a wide range of people with high-end skills and knowledge at reasonable prices. This information clearly shows that all the companies have the same vision of AI as the leader of future technological development. The interest in new AI technologies and their use cases indicates an initiative-taking approach not only to enhancing existing processes but also to adopting new technologies. This focus to keep on innovating ourselves and staying relevant to changes in the

marketplace explains how AI is expected to transform the future of business and technology.

5.10 AI Implementation Recommendations

The analysis of interviews with people from Company 1, Company 2, and Company 3 has given us valuable information on how to improve AI implementation in different industries. Based on what we learned, here are some recommendations to help address challenges and make the most of opportunities. These focus on key themes like strategic adaptation, overcoming hesitancy, and building trust and understanding in AI technologies.

1. **Strategic Integration**: Companies should start small AI projects that can show clear benefits. This also helps minimize risks and provides learning to improve the process of adaptation. By focusing on these areas where the companies will get results easily, can help to gradually extend the use of AI, while gaining trust and experience.
2. **Enhancing Transparency and Trust:** To make AI more trustworthy, companies need to make AI systems as transparent and understandable as possible. This means developing AI that can explain its decisions clearly and reducing the "black box" nature of AI. Transparency of AI helps in improving the understanding, increasing people’s trust, and making AI more widely accepted and integrated.
3. **Promoting AI Knowledge**: It is crucial for companies to invest in education and training to increase AI awareness across different levels of organizations. By making AI available to every employee, not only professionals, but organizations

can also increase its value for the common workers as well as the volume of suggestions and innovations. Training should explain how AI works and how AI can be applied in business and solve business problems.

4. **Ensuring Ethical and Secure** Ethical factors and the protection of data are some of the critical factors that should guide the adoption of AI technologies. Businesses require good ethical standards and measures on how to deal with the risks resulting from the implementation of AI. This is good for the company to avoid leakage of information and compliance issues and customers to be confident that the company follows proper ethical measures.
5. **Using Industry-Specific Insights**: AI applications must be industry specific and designed according to the requirements of an industry. Because AI solutions are industry-specific, it is essential for organizations to understand existing models and include these findings into practical solutions for the organization. This approach helps ensure that the AI processes are efficient and provide a positive impact on operation and innovation.
6. **Improve Integration Techniques for Machines**: To get the full benefits of AI, companies should develop integration strategies that enable integration of machines to AI systems. This involves the development of advanced sensor devices, adaptive actuators, and smart control mechanisms that can interpret AI findings and implement them.
7. **Design AI-Capable Machines**: There is a primary requirement to have systems that are designed and compatible to work with AI. These machines should be optimized to have more functionality that is supported by AI algorithms and data

analysis. Creating such machines requires the combined effort of mechanical engineers and software developers and AI experts to ensure that the hardware and software are compatible, scalable and optimizable with future advancement in AI technology.

It is important to note that the theme of AI aligning with requirements practices by the company appeared often throughout the interview and should be a major consideration during AI implementation. This recognition of requirements is supported by previous research (56-60). By following these recommendations, companies can improve their AI strategies, ensuring that AI is integrated in a strategic, trusted, and beneficial way. These practices will help solve some of the existing issues and can open the path to the further efficient utilization of AI in the industry.

CHAPTER 6

CONCLUSION

There are big challenges and great opportunities to address when using AI and automation in manufacturing. This study looked at these issues through a detailed review of research and interviews with people from Company 1, Company 2, and Company 3. The main problems include the technical difficulties of adding new AI systems to existing ones, high costs, skill gaps in the workforce, and ethical issues like job loss and bias. These are the problems that need to be solved for the move from Industry 4.0 to Industry 5.0 and beyond. Research review also involved the use of various AI technologies in the industry such as robotics, big data, IoT, cognitive systems etc. This would use academic papers, industry reports and case studies that would give a complete picture of the current state of AI in the manufacturing sector. This stated that AI systems should address the needs of industries, while in the time when the Publications are expected by AI to be meaningful and beneficial to human. Nine major concern areas are identified in the interviews in relation to their impact on the companies. Some of these themes are what role does AI play in companies, how do companies benefit from AI, how do companies view AI, how they utilize AI, their strengths, weaknesses, concerns, awareness, and confidence. The recommendations include the initiation of AI projects on a smaller scale and the expansion of these projects over time, making AI systems transparent and understandable, offering education and training on AI, tackling important ethical and security challenges, and delivering industry-specific expertise to adapt AI use-

cases. This research highlights the necessity to adopt AI with a considerable range and move forward with better standards rather than rapid deployment or just using it randomly, and the importance of balancing innovation with risk and ethical concerns. With those recommendations in mind, companies will have what they need to address and minimize the risks associated with AI adoption and to make better decisions on how to use AI to boost innovation and efficiency in a satisfactory, legal, and purposeful manner.

In summary, this study offers a guide for the manufacturers who would like to implement AI and automation. It highlights the importance of continuous learning, clear practices, and focusing on industry-specific solutions to overcome challenges and fully benefit from AI in manufacturing.

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