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Artificial Intelligence and Lean Entrepreneurship among Selected Manufacturing Firms in Nigeria

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Abstract*: This study examined the relationship between artificial intelligence (AI) and lean entrepreneurship among Nigerian manufacturing firms. The specific objective was to ascertain the contribution of AI-powered financial modeling and AI-powered market research towards lean entrepreneurship among selected manufacturing firms in Nigeria. The study employed a descriptive survey research design to gather data from participants on the relevant variables. Cochran's formula was used to determine the appropriate sample size 384 respondents drawn from manufacturing firms in Nigeria. Primary data were gathered using a structured questionnaire, designed with a 5-point Likert scale to assess various constructs. The data were analyzed using descriptive statistics, including frequency counts. For hypothesis testing, inferential analysis was conducted at a 5% significance level using Spearman's Correlation Analysis, performed with the Statistical Package for the Social Sciences (SPSS) Version 25. The findings revealed that: AI-powered financial modeling significantly and positively contributes to lean entrepreneurship among selected manufacturing firms in Nigeria (Spearman's rho = 0.845; p-value of 0.000); AI-powered market research significantly and positively influences lean entrepreneurship among selected manufacturing firms in Nigeria (Spearman's rho = 0.852; p-value of 0.000). In conclusion, the strategic adoption of AI and lean entrepreneurship principles could provide the impetus needed for the manufacturing sector to achieve sustained growth and competitiveness. It is recommended that manufacturing firms in Nigeria should invest in AI-driven financial modeling tools to enhance their financial decision-making processes since this will enable the firms to optimize resource allocation, reduce waste, and improve operational efficiency, which are essential for adopting lean entrepreneurship practices effectively.*

Keywords: Artificial Intelligence, Lean Entrepreneurship, AI-Powered Financial Modeling, AI-Powered Market Research

Introduction

In recent years, the global business environment has undergone rapid transformations driven by technological advancements, shifts in consumer behaviour, and evolving economic landscapes. Among the most notable of these transformations is the integration of Artificial Intelligence (AI) into various facets of business operations (Ughulu, 2022). AI, once a futuristic concept, has become a cornerstone of modern industries, reshaping how businesses function, compete, and innovate. This technological evolution is not limited to advanced economies; developing nations like Nigeria are also experiencing the ripple effects of AI adoption. At the same time, the concept of lean entrepreneurship, which emphasizes minimizing waste and maximizing value creation with limited resources (Ufua, Olujobi, Tahir, Al-Faryan, Matthew & Osabuohien, 2022), has gained traction as a viable strategy for businesses operating in resource-constrained environments. The convergence of AI and lean entrepreneurship presents a unique opportunity for Nigerian manufacturing firms to enhance their competitiveness and sustainability in a rapidly changing global market.

In an era characterized by volatility, uncertainty, complexity, and ambiguity (VUCA) (Topor, 2024), businesses must continuously adapt and innovate to survive and thrive. AI offers unprecedented capabilities to analyze vast amounts of data, automate complex processes, and enable intelligent decision-making, all of which are critical for maintaining a competitive edge. For manufacturing firms, AI can optimize supply chain management, enhance product quality, reduce operational costs, and accelerate innovation cycles (Widayanti & Meria, 2023). Simultaneously, lean entrepreneurship provides a strategic framework for businesses to operate efficiently, by focusing on customer value, continuous improvement, and the prudent use of resources (Balocco, Cavallo, Ghezzi & Berbegal-Mirabent, 2019). This approach is particularly relevant in emerging economies like Nigeria, where businesses often face challenges such as limited access to capital, infrastructural deficiencies, and fluctuating market conditions. By integrating AI with lean entrepreneurship, Nigerian manufacturing firms can not only overcome these challenges but also create new avenues for growth and development.

Artificial Intelligence refers to the simulation of human intelligence in machines, enabling them to perform tasks that typically require human cognition, such as learning, reasoning, problem-solving, and decision-making. AI encompasses various subfields, including machine learning, natural language processing, computer vision, and robotics, each of which contributes to its broad application across industries (Mokhtar & Salimon, 2022). In the context of manufacturing, AI can be applied to areas such as

predictive maintenance, quality control, supply chain optimization, and product design, among others. Lean entrepreneurship, on the other hand, is a business methodology that advocates for creating more value for customers with fewer resources. Rooted in the principles of lean manufacturing, which originated in the Japanese automotive industry, lean entrepreneurship emphasizes customer-centric innovation, rapid prototyping, and iterative development. It encourages entrepreneurs to focus on delivering products or services that meet customer needs while eliminating wasteful practices that do not add value to the end user.

The intersection of AI and lean entrepreneurship presents a compelling case for how technology can drive more efficient and innovative business practices (Ale, Daniyan, Aderoba, & Adediran, 2024). AI's ability to process and analyze large datasets can provide valuable hints into customer behavior, market trends, and operational efficiencies, all of which are crucial for lean entrepreneurs. For instance, AI can help entrepreneurs quickly validate business ideas by analyzing market data and predicting customer responses, thus reducing the time and resources spent on unviable projects. Additionally, AI-driven automation can streamline production processes, reduce lead times, and minimize errors, aligning with the lean principles of efficiency and waste reduction. In the manufacturing sector, AI-powered systems can optimize inventory management, forecast demand with greater accuracy, and enhance the quality of products through real-time monitoring and adjustments. By leveraging AI, lean entrepreneurs can make data-driven decisions that enhance their ability to pivot quickly in response to market changes, thus maintaining a competitive edge (Ughulu, 2022).

In Nigeria, where the manufacturing sector faces numerous challenges such as inconsistent power supply, inadequate infrastructure, and limited access to finance, the adoption of AI and lean entrepreneurship could be transformative. Nigerian manufacturing firms that embrace AI stand to benefit from increased operational efficiency, reduced production costs, and improved product quality, all of which are essential for competing in both domestic and international markets. Furthermore, the lean entrepreneurship approach can help these firms maximize the value they deliver to customers while minimizing resource usage, making them more resilient in the face of economic uncertainties (Ale, Daniyan, Aderoba, & Adediran, 2024). The integration of AI into lean entrepreneurship practices in Nigerian manufacturing firms could also stimulate innovation by enabling businesses to experiment with new ideas and rapidly iterate on them based on real-time data and customer feedback. This could lead to the development of new products, services, and business models that cater to the unique needs of the Nigerian market, while also positioning these firms to compete on a global scale.

However, the adoption of AI in Nigeria's manufacturing sector remains limited, hindered by several challenges, including inadequate infrastructure, lack of skilled personnel, and insufficient financial resources to invest in advanced technologies. Additionally, the concept of lean entrepreneurship, while recognized, has not been widely implemented across the sector. Many firms continue to rely on outdated business practices that are less focused on efficiency and more on short-term gains. As a result, many Nigerian manufacturing firms apparently struggle to incorporate AI effectively into their operations, missing out on the potential benefits that could drive their competitiveness and sustainability in the long term.

Thus, without the effective adoption of AI and lean entrepreneurship practices, Nigerian manufacturing firms face numerous challenges, including inefficiencies in production, higher operational costs, and limited innovation. These issues not only hinder the ability of these firms to compete on a global scale but also reduce their profitability and sustainability. The lack of innovation driven by AI leads to a stagnation in product development and limits opportunities for market expansion. Moreover, the inefficiencies associated with the failure to adopt lean practices result in increased wastage and resource mismanagement, further exacerbating the financial strain on these firms. In the long run, the continued reliance on outdated practices and the slow adoption of AI threaten the survival of Nigerian manufacturing firms in an increasingly competitive and technologically advanced global market.

In the light of the above, this study examines the extent to which AI has contributed to lean entrepreneurship among Nigerian manufacturing firms. The specific objectives are as follows:
1) To examine the contribution of AI-powered financial modeling on lean entrepreneurship among selected manufacturing firms in Nigeria.
2) To assess the extent to which AI-powered market research influences lean entrepreneurship among selected manufacturing firms in Nigeria.

Justification for the Study and Gap in Literature

While significant research has explored the role of Artificial Intelligence (AI) in various aspects of entrepreneurship and industry transformation, a gap remains in understanding the specific contributions of AI to lean entrepreneurship within the context of Nigerian manufacturing firms. Studies such as those conducted by Ale, Daniyan, Aderoba, and Adediran (2024) have focused on AI-based frameworks for smart manufacturing, and Itai, Emena, and Daniel (2024) examined the impact of AI on the growth of SMEs in Nigeria, but these works primarily address broader industrial applications rather than the lean principles that are critical to entrepreneurship. Similarly, Raneri, Lecron, Hermans, and Fouss (2023) have highlighted the integration of AI in the Lean Startup

methodology, yet their focus remains on predictive algorithms in digital product design rather than the financial modeling and market research integral to lean entrepreneurship. Shepherd and Majchrzak (2022) discussed the potential of AI as a super tool for entrepreneurship, but their work lacks an in-depth analysis of how AI-driven financial and market research tools contribute to lean entrepreneurial practices, especially in developing economies like Nigeria.

Further, existing studies by Chalmers, MacKenzie, and Carter (2021) and Pfau and Rimpp (2021) have delved into AI's impact on new venture processes and business models, respectively, but these analyses often overlook the lean aspect, which focuses on maximizing efficiency while minimizing waste—key components in the entrepreneurial context. Lekan, Clinton, Fayomi, and James (2020) examined the relationship between lean construction and Industry 4.0, but this does not translate directly to lean entrepreneurship within the manufacturing sector. Sharma (2019) and Shiyal, Garg, and Rohini (2019) have also investigated the intersection of AI and entrepreneurship, but their studies either concentrate on broader economic implications or compare traditional techniques with AI, without a focused analysis on lean entrepreneurship. Therefore, this study fills a critical gap by specifically examining the contributions of AI-powered financial modeling and market research to lean entrepreneurship among Nigerian manufacturing firms, a topic that has not been adequately addressed in the existing literature.

Hypotheses

H01) AI-powered financial modeling does not significantly contribute to lean entrepreneurship among selected manufacturing firms in Nigeria.
H02) AI-powered market research does not significantly influence lean entrepreneurship among selected manufacturing firms in Nigeria.

Literature Review

Conceptual Review

Artificial Intelligence

Artificial Intelligence (AI) refers to the simulation of human intelligence in machines that are programmed to think, learn, and make decisions in a manner similar to humans (Ale, Daniyan, Aderoba, & Adediran, 2024). AI encompasses a broad range of computational techniques and systems that enable machines to perform tasks that typically require human intelligence (Itai, Emena & Daniel, 2024). These tasks include, but are not limited to, problem-solving, pattern recognition, language understanding, learning from experience, and adapting to new situations. AI systems achieve these capabilities through the use of algorithms and data, which allow them to analyze information, recognize patterns, and generate responses or actions based on the hints gained from the data (Cautela, Mortati, Dell'Era & Gastaldi, 2019). AI can operate in various forms, ranging from simple rule-based systems to complex neural networks that mimic the human brain's structure and functioning.

One of the fundamental aspects of AI is its ability to learn and improve over time, a process known as machine learning. Machine learning allows AI systems to process vast amounts of data, identify patterns, and refine their algorithms to enhance performance without explicit human intervention. This capability enables AI to adapt to new inputs and perform tasks with increasing accuracy as it is exposed to more data. AI can be categorized into different types based on its capabilities, including narrow AI, which is designed to perform specific tasks, and general AI, which is a more advanced form of AI that possesses the ability to perform any intellectual task that a human can do. Narrow AI is the most prevalent form in use today, powering applications such as voice assistants, recommendation systems, and autonomous vehicles.

AI has a wide range of applications across various industries, including healthcare, finance, manufacturing, and customer service (Cautela, Mortati, Dell'Era & Gastaldi, 2019). In healthcare, AI is used for diagnosing diseases, predicting patient outcomes, and personalizing treatment plans. In finance, AI systems are employed for fraud detection, algorithmic trading, and risk management. In manufacturing, AI optimizes production processes, predicts equipment failures, and enhances product quality. The ability of AI to process and analyze large volumes of data in real-time makes it a valuable tool for businesses seeking to improve efficiency, reduce costs, and gain a competitive edge in the market (Ale, Daniyan, Aderoba, & Adediran, 2024). Despite its potential, AI also raises ethical and societal concerns, particularly regarding data privacy, job displacement, and the potential for bias in decision-making algorithms (Itai, Emena & Daniel, 2024; Mmadubuobi, Nworie & Aziekwe, 2024). As AI continues to evolve, it will play an increasingly significant role in shaping the future of technology and society.

AI-powered Financial Modeling

AI-powered financial modeling refers to the use of Artificial Intelligence (AI) technologies to create, analyze, and enhance financial models that help organizations make informed decisions regarding their financial strategies, investments, and risk management (Uddin, Jamal, Umair, Khader & Kumar, 2024). Traditional financial modeling relies on mathematical and statistical techniques to forecast financial performance, assess risks, and evaluate the impact of various financial scenarios. However, AI-powered financial

modeling takes this process a step further by incorporating machine learning algorithms, natural language processing, and other AI techniques to analyze vast amounts of financial data, identify complex patterns, and generate hints that may not be readily apparent through conventional methods (Rane, Choudhary & Rane, 2023).

One of the key advantages of AI-powered financial modeling is its ability to process and analyze large datasets quickly and accurately. This capability is particularly valuable in today's data-driven financial environment, where organizations are inundated with vast amounts of information from various sources, including financial statements, market data, economic indicators, and news reports. AI algorithms can sift through this data, identify relevant trends, and incorporate them into financial models, enabling organizations to make more accurate and timely predictions. AI-powered financial modeling also enables the automation of routine tasks, such as data collection, processing, and analysis. This automation not only reduces the time and effort required to build and maintain financial models but also minimizes the risk of human error, which can lead to inaccurate forecasts or faulty financial decisions (Rane, Choudhary & Rane, 2023). Moreover, AI can enhance the transparency and interpretability of financial models by providing explanations for its predictions and identifying the factors that drive its outcomes. This level of transparency is crucial for gaining the trust of stakeholders and ensuring that AI-powered financial models are used responsibly and effectively within organizations.

AI-powered Market Research

AI-powered market research refers to the use of Artificial Intelligence (AI) technologies to gather, analyze, and interpret data related to consumer behavior, market trends, and competitive landscapes (Daline & Thomas, 2024). Market research traditionally involves the collection and analysis of data through surveys, interviews, focus groups, and other methods to gain hints into customer preferences, purchasing habits, and market dynamics. AI-powered market research enhances this process by leveraging machine learning algorithms, natural language processing, and data analytics to process large volumes of data from various sources quickly and accurately, providing businesses with deeper hints and more actionable intelligence (Deveau, Griffin & Reis, 2023).

One of the primary advantages of AI-powered market research is its ability to analyze unstructured data, such as social media posts, customer reviews, and online discussions (Daline & Thomas, 2024). Traditional market research methods often struggle to process and make sense of such data, which is typically vast, varied, and constantly evolving. However, AI technologies, particularly natural language processing (NLP), can analyze text data to identify patterns, sentiments, and emerging trends that might be overlooked by conventional methods. AI-powered market research also enhances the speed and efficiency of data analysis (Odubanjo, 2024). By automating the collection and processing of data, AI can provide businesses with real-time hints that are crucial for making timely decisions in a fast-paced market environment.

Moreover, AI-powered market research can also enhance predictive capabilities (Daline & Thomas, 2024). By analyzing historical data and identifying patterns, AI can forecast future market trends, predict consumer behavior, and assess the potential impact of various marketing strategies. These predictive hints allow businesses to make more informed decisions about product development, pricing, distribution, and promotional activities, ultimately leading to more effective marketing strategies and better business outcomes.

Lean Entrepreneurship

Lean entrepreneurship is a business methodology that emphasizes the creation of value for customers while minimizing waste and optimizing the use of resources (Ovharhe, Chibuike & Abada, 2023). This approach draws inspiration from lean manufacturing principles, which originated in the Japanese automotive industry, particularly within Toyota. Lean entrepreneurship focuses on maximizing efficiency, reducing costs, and delivering high-quality products or services that meet customer needs with minimal waste of time, money, and resources. It is particularly relevant in today's fast-paced, resource-constrained business environment, where entrepreneurs must be agile, innovative, and resourceful to succeed (Ufua et al., 2022).

The essence of lean entrepreneurship is the concept of the Minimum Viable Product (MVP), which involves developing a basic version of a product or service that meets the essential needs of customers (Moogk, 2012). The MVP is then tested in the market, and based on customer feedback, it is iteratively improved. This process allows entrepreneurs to validate their business ideas quickly and at a low cost, reducing the risk of failure and ensuring that resources are only invested in ideas that have been proven to have market potential. By focusing on the MVP, lean entrepreneurs avoid the common pitfall of over-investing in product development before market validation, which can lead to significant waste of time and resources.

Lean entrepreneurship also emphasizes the importance of continuous improvement and learning (Ovharhe, Chibuike & Abada, 2023). Entrepreneurs are encouraged to engage in a cycle of build, measure, and learn, where they constantly test assumptions, gather data, and refine their products or services based on customer feedback. This iterative process helps entrepreneurs stay attuned to market needs and adapt quickly to changes in customer preferences or market conditions. By maintaining a customer-centric focus and being willing to pivot when necessary, lean entrepreneurs can increase their chances of success while minimizing the risks associated with traditional business models.

Another key aspect of lean entrepreneurship is the efficient use of resources (Balocco, Cavallo, Ghezzi & Berbegal-Mirabent, 2019). Lean entrepreneurs are mindful of how they allocate their time, money, and efforts, striving to achieve maximum impact with minimal input. This resource-conscious approach is particularly important for startups and small businesses, which often operate with limited budgets and must make every dollar count. By prioritizing high-impact activities and avoiding wasteful practices, lean entrepreneurs can achieve greater efficiency and sustainability in their operations (Ovharhe, Chibuike & Abada, 2023).

Lean entrepreneurship also promotes a culture of experimentation and innovation. Entrepreneurs are encouraged to test new ideas, explore unconventional solutions, and take calculated risks in pursuit of business success (Boute, Gijsbrechts & Van Mieghem, 2022). This culture of innovation is essential for staying competitive in a rapidly evolving market and for discovering new opportunities for growth. By fostering an environment where experimentation is encouraged, lean entrepreneurship enables businesses to continuously evolve and stay ahead of the competition.

Theoretical Framework

The Lean Startup Theory was introduced by Eric Ries in 2008 as a methodology for developing businesses and products (Villalobos, Vargas, Rodriguez & Araya-Castillo, 2018). This theory draws from principles of lean manufacturing, which were originally developed by Toyota in the mid-20th century. Ries adapted these principles to the context of startups, emphasizing the need for efficiency and the reduction of waste in the entrepreneurial process. The Lean Startup Theory advocates for a systematic, scientific approach to creating and managing startups, where entrepreneurs continuously test their hypotheses, learn from customer feedback, and iteratively develop their products. This method aims to increase the chances of success by ensuring that resources are directed toward creating products that meet market needs (Heitmann, 2014).

The main postulations of the Lean Startup Theory revolve around three key concepts: the Minimum Viable Product (MVP), validated learning, and the build-measure-learn feedback loop (Boyd, 2017). The MVP is a version of a product that contains only the most essential features, allowing entrepreneurs to quickly test their ideas in the market with minimal investment. Validated learning refers to the process of using data and customer feedback to verify that the product meets a real need or solves a genuine problem. The build-measure-learn feedback loop is a cycle in which entrepreneurs build an MVP, measure how it performs in the market, and learn from the results to improve the product. This iterative process allows for continuous adaptation and improvement, reducing the risk of failure and optimizing the use of resources (Leatherbee & Katila, 2020).

The Lean Startup Theory is particularly relevant to the topic of the effect of Artificial Intelligence on lean entrepreneurship among selected manufacturing firms in Nigeria. AI technologies can significantly enhance the principles of lean entrepreneurship by providing sophisticated tools for data analysis, customer feedback collection, and rapid prototyping. By integrating AI into the Lean Startup methodology, manufacturing firms can more effectively develop MVPs, conduct validated learning, and iterate their products based on real-time data. This alignment between AI and lean entrepreneurship helps firms minimize waste, reduce time-to-market, and increase the likelihood of creating products that resonate with customers. The Lean Startup Theory, therefore, provides a strong theoretical foundation for understanding how AI can drive lean entrepreneurial practices in the manufacturing sector.

Empirical Review

Ale, Daniyan, Aderoba, and Adediran (2024) examined the development of an Artificial Intelligence-based integrated digital technology framework for lean and smart manufacturing implementation. Some technologies and techniques driving Industry 4.0 that are considered in this study include Additive Manufacturing, Automatic Train Control, smart sensors, Internet of Things, big data, cloud computing, Total Productive Maintenance, Predictive Maintenance, and Artificial Intelligence. Using the rail industry as a case study, an overview of the enabling technologies was presented to acquaint the manufacturing industries with the potentials and applications of these technologies to manufacturing. The study also develops a conceptual framework that incorporates the main driving technologies of lean and smart manufacturing for adoption by the rail industry. The validation of the proposed integrated framework involves the use of AI technology for total productive and predictive maintenance using the rail industry as a case study and was conducted in the MATLAB 2020 b environment. The outcome of the demonstration shows the Remaining Useful Life of a bearing component of a railcar can be predicted using AI. The predicted Remaining Useful Life of the wheel bearing indicates 500 hours over the next 40 days before failure occurs. Thus, this study adds to the understanding of AI in the lean and smart manufacturing

domain. The implementation of the integrated framework can promote efficiency and effectively service delivery in industries that employ the concept of lean and smart manufacturing.

Itai, Emena, and Daniel (2024) examined the relationship between Artificial Intelligence, innovation, employment, and growth of SMEs in Nigeria. Principal component analysis and the structural equation model were used to examine the role of AI in SMEs growth in South West, Nigeria. The population of the study focused on SMEs firms engaging in manufacturing, hospitality, information and communication, and administrative and support services sectors. A sample size of 322 was adopted from Krejcie and Morgan's research table of a population size of 2,000. The results of the study showed that AI innovation indicators have a positive relationship with SMEs growth. It was also observed that AI employment indicators exert a direct relationship with the latent factor. Overall results showed that applications of AI construct indicators remain strong on SMEs growth.

Raneri, Lecron, Hermans, and Fouss (2023) conducted a study titled "Predictions through Lean startup? Harnessing AI-based predictions under uncertainty". Based on effectuation theory, this study identifies an AI-based, predictive phase in the "build-measure-learn" loop of Lean startup. The predictive component, based on recommendation algorithm techniques, is integrated into a framework that considers both prediction (causal) and controlled (effectual) logics of action. The performance of the so-called active learning build-measure-predict-learn algorithm is evaluated on a data set collected from a case study. The results show that the algorithm can predict the desirability level of newly implemented product design decisions in the context of a digital product. The main advantages, in addition to the prediction performance, are the ability to detect cases where predictions are likely to be less precise and an easy-to-assess indicator for product design desirability. The model is found to deal with uncertainty in a threefold way: epistemological expansion through accelerated data gathering, ontological reduction of uncertainty by revealing prior "unknown unknowns," and methodological scaffolding, as the framework accommodates both predictive (causal) and controlled (effectual) practices.

Shepherd and Majchrzak (2022) explain AI and look into the future to highlight some of AI's broader and longer-term societal implications. They propose that AI can be combined with entrepreneurship to represent a super tool. Scholars can research the nexus of AI and entrepreneurship to explore the possibilities of this potential AI-entrepreneurship super tool and hopefully direct its use to productive processes and outcomes. They focus on specific entrepreneurship topics that benefit from AI's augmentation potential and acknowledge implications for entrepreneurship's dark side.

Chalmers, MacKenzie, and Carter (2021) explore the ways artificial intelligence may impact new venture processes, practices, and outcomes. They examine how such technology will augment and replace tasks associated with idea production, selling, and scaling. These changes entail new ways of working, and they consider implications for the organizational design of entrepreneurial ventures. While AI can enhance entrepreneurial activities, liabilities stem from this technological leverage. They advance a research agenda that draws attention to negative social and economic implications of AI, particularly for more traditional small firms at risk of disintermediation in an AI economy.

Pfau and Rimpp (2021) classified the roles of artificial intelligence applications on the strategic level and their influence on business models. By means of case studies, current business practice is examined to give entrepreneurs and researchers an understanding of this technology, by providing practical examples so that they can pursue their own AI path. The analysis is based on case studies that examine the role of AI in a company’s business model, both for new market participants in the form of start-ups and incumbents such as the tech giants. By means of case studies, both sides of the extremes are covered in order to provide a picture of the scope of the applications. Hints from these case studies are processed to develop a classification scheme of the influence of AI on business models. Furthermore, the interaction of the different innovation possibilities of AI is compared and with that the importance of the innovative power of companies. Additionally, strategy types are developed on the basis of the presented classification scheme, but give entrepreneurs a suggestion for their own AI path in terms of AI applications to consider.

Lekan, Clinton, Fayomi, and James (2020) examined the relationship between lean construction and Industry 4.0. The purposive sampling method was used in this study to collect data. The data collection instrument consists of a structured questionnaire designed in a Likert scale of 1 to 5 distributed to 100 construction professionals through an online method that is actively involved in construction operations. The following parameters were censored and profiled, while the results are in tables and charts. The parameters include areas of lean thinking that could enhance Construction 4.0, areas of disruption in Industry 4.0 that influence Construction 4.0 advancement, and parameters for practical integrating of lean thinking approach and Industry 4.0. Additionally, the influence of Industry 4.0 in technological development for the construction industry, disruptive innovation of Industry 4.0 and gains towards Construction 4.0. Furthermore, the relevance of Construction 4.0 in construction productivity, the importance of Construction 4.0, industrial application drivers in achieving Construction 4.0, the future of Construction 4.0, achieving automation goals in construction and performance expectations of lean thinking and Industry 4.0 in the construction industry are found necessary. Simple percentage, Spearman rankings, Chi-square test, Student-T test, Mann–Whitney-U test, and Relative Agreement and Importance index are the tools used to process the data. The study discovered, among others, the veracity of a contingency approach in harnessing attributes of the lean thinking concept and disruptive applications in achieving Construction 4.0.

Sharma (2019) investigates several inhibitors of entrepreneurship in the perpetual economy of India. The study further explores the different motivators of entrepreneurship and examines the impact of those entrepreneurial motivators on economic growth and employment. A focus group interview was conducted with entrepreneurs in 2017. Nowadays, advancements in technology and Artificial Intelligence have touched every sphere of our life. This paper tries to focus on the impact made by AI in entrepreneurial activities. In general, factors that enrich entrepreneurship include encouraging social entrepreneurship, improving the institutional environment, and support from international organizations. For the growth of the country, practical implications have been identified, such as improving institutional development, creating a supportive business environment with e-commerce, and promoting social entrepreneurship and security.

Shiyal, Garg, and Rohini (2019) conducted a study on the Usage and Implementation of Artificial Intelligence in Entrepreneurship. The research includes a sample size of 50 responses. Structured questionnaires were distributed among the entrepreneurs, along with personal interviews to find out their perception of traditional techniques versus artificial intelligence and also to analyze the relationship between traditional techniques and artificial intelligence and their impact on the decision of entrepreneurship. The results revealed that personality and compatibility tests have a statistically significant difference in the perception of men and women entrepreneurs.

Methodology

The study employed a descriptive survey research design to gather data from participants on the relevant variables. Descriptive research primarily seeks to provide a depiction of the current situation (Nworie, Okafor, Igwebuike & Onyali, 2023). In this study, the descriptive survey approach was used to gather information from respondents about the existing state of the phenomenon, with the aim of outlining "what exists" in relation to variables or conditions within a particular context. The study targeted employees of manufacturing enterprises in Nigeria, where no comprehensive register captures the demographic details of all staff in the sector. Given this limitation, the population for the study was considered infinite, necessitating the use of Cochran's formula to determine the appropriate sample size, which indicated that approximately 384 respondents were needed to achieve statistical validity.

$$n = \frac{Z^2 \cdot p \cdot (1-p)}{E^2}$$

Where:

n = sample size

Z = Z-value (the number of standard deviations from the mean, typically 1.96 for a 95% confidence level)

p = estimated proportion of the population (0.5 is used if no prior estimate is available)

E = margin of error (expressed as a decimal, e.g., 0.05 for 5%)

$$n = \frac{1.96^2 \cdot 0.5 \cdot (1-0.5)}{0.05^2}$$

n = 384 respondents

Primary data were gathered using a structured questionnaire, designed with a 5-point Likert scale to assess various constructs. This approach allowed participants to answer questions at their own pace, enhancing response accuracy. The questionnaire was chosen as the data collection instrument to ensure uniformity, with all participants receiving the same questions in a consistent format. The data were analyzed using descriptive statistics, including frequency counts. For hypothesis testing, inferential analysis was conducted at a 5% significance level using Spearman's Correlation Analysis, performed with the Statistical Package for the Social Sciences (SPSS) Version 25. Spearman correlation was selected due to its appropriateness for ordered or ranked data, which aligns well with the Likert scale responses used in this study. A significance level of 5% was set, meaning that if the p-value was below 0.05, the null hypothesis would be rejected in favor of the alternative. Conversely, a p-value above 0.05 would support the null hypothesis.

Data Analysis

Analysis of Research Questions

Out of the 384 sample expected 361 responded to the research instrument. Table 4.1 below shows the analysis of the research questions according to the number of responses obtained.

Table 4.1 Analysis of Research Question

S/N	AI-powered Financial Modeling	SA	A	U	D	SD	Mean	Remark
1	AI-powered financial modeling improves the accuracy of our financial forecasts.	204	60	73	24	0	4.23	Accept
2	The integration of AI in financial modeling helps our organization make better-informed investment decisions.	222	0	114	25	0	4.16	Accept
3	AI-based financial models in our organization have enhanced our ability to identify potential financial risks.	228	91	42	0	0	4.52	Accept
4	Our organization relies on AI-powered financial modeling to optimize our financial performance.	222	90	49	0	0	4.48	Accept
S/N	**AI-powered Market Research**	**SA**	**A**	**U**	**D**	**SD**	**Mean**	**Remark**
5	The use of AI in market research has improved our understanding of market trends and dynamics.	186	78	48	49	0	4.11	Accept
6	AI-driven market research enables our organization to make more informed marketing decisions.	186	78	49	48	0	4.11	Accept
7	AI-powered tools have increases the speed and efficiency of our market research processes.	226	0	84	49	2	4.11	Accept
8	Our organization benefits from more accurate market forecasts due to AI-powered market research.	246	42	24	24	25	4.27	Accept
S/N	**Lean Entrepreneurship**	**SA**	**A**	**U**	**D**	**SD**	**Mean**	**Remark**
9	Our organization minimizes waste and optimizes resource use.	180	66	66	0	49	3.91	Accept
10	We focus on creating a Minimum Viable Product (MVP) to validate our business ideas quickly and cost-effectively.	192	60	60	24	25	4.02	Accept
11	Continuous improvement and learning are central to our business strategy under lean entrepreneurship.	192	18	108	18	25	3.93	Accept
12	Lean entrepreneurship allows us to pivot quickly in response to customer feedback and market changes.	228	0	84	24	25	4.06	Accept

Source: Field survey, August 2024

The frequency table provides an analysis of responses related to AI-powered financial modeling, AI-powered market research, and lean entrepreneurship.

For the item regarding AI-powered financial modeling's impact on the accuracy of financial forecasts, 204 respondents strongly agreed, 60 agreed, 73 were undecided, 24 disagreed, and none strongly disagreed, yielding a mean score of 4.23. This high mean score suggests that the majority of respondents perceive AI-powered financial modeling as significantly improving the accuracy of their financial forecasts, reflecting a strong acceptance of this technology's benefit.

In the next item, respondents were asked about the integration of AI in making better-informed investment decisions. Here, 222 strongly agreed, none agreed, 114 were undecided, 25 disagreed, and none strongly disagreed, with a mean score of 4.16. The high number of strong agreements indicates a consensus on the positive impact of AI integration on investment decisions, though the lack of agreement responses shows a clear differentiation in perception.

The third item assessed whether AI-based financial models have enhanced the ability to identify potential financial risks. With 228 strongly agreeing, 91 agreeing, 42 undecided, and no disagreements, the mean score of 4.52 suggests a strong belief that AI significantly improves risk identification capabilities, with minimal dissent among respondents.

For the fourth item, concerning reliance on AI-powered financial modeling to optimize financial performance, 222 strongly agreed, 90 agreed, 49 were undecided, and none disagreed or strongly disagreed, resulting in a mean score of 4.48. This indicates a robust acceptance of AI's role in optimizing financial performance, with strong support and minimal opposition.

Turning to AI-powered market research, the first item explores whether AI improves understanding of market trends and dynamics. Here, 186 strongly agreed, 78 agreed, 48 were undecided, 49 disagreed, and none strongly disagreed, with a mean score of 4.11. This suggests a generally positive view of AI's contribution to understanding market trends, though there is a notable proportion of disagreement and undecision.

In the second item, respondents evaluated whether AI-driven market research enables more informed marketing decisions. The distribution of responses, with 186 strongly agreeing, 78 agreeing, 49 undecided, and 48 disagreeing, also results in a mean score of

4.11. This indicates a favorable opinion on AI's role in enhancing marketing decisions, though similar to the previous item, there is a significant portion of disagreement.

The third item on the efficiency of market research processes shows that 226 respondents strongly agreed, none agreed, 84 were undecided, 49 disagreed, and 2 strongly disagreed, with a mean score of 4.11. This suggests that AI is perceived to substantially increase the speed and efficiency of market research, though there is a small percentage of disagreement.

Lastly, the item regarding benefits from accurate market forecasts due to AI-powered market research shows 246 strong agreements, 42 agreements, 24 undecideds, 24 disagreements, and 25 strong disagreements, with a mean score of 4.27. This high mean score reflects a strong belief in the accuracy improvements provided by AI in market forecasting, although there is some dissent.

For lean entrepreneurship, the item on minimizing waste and optimizing resource use shows 180 strongly agreed, 66 agreed, 66 undecided, none disagreed, and 49 strongly disagreed, with a mean score of 3.91. This indicates general acceptance of lean principles, though the significant number of strong disagreements suggests some challenges in implementing these practices.

The next item on creating a Minimum Viable Product (MVP) for quick validation of business ideas has 192 strongly agreeing, 60 agreeing, 60 undecided, 24 disagreeing, and 25 strongly disagreeing, resulting in a mean score of 4.02. This suggests a strong endorsement of the MVP approach as an effective strategy under lean entrepreneurship, despite some disagreements.

In the third item, focusing on continuous improvement and learning as central to the business strategy, 192 respondents strongly agreed, 18 agreed, 108 were undecided, 18 disagreed, and 25 strongly disagreed, with a mean score of 3.93. This indicates general support for continuous improvement within lean entrepreneurship, though there are notable disagreements.

The final item assesses whether lean entrepreneurship allows for quick pivots in response to customer feedback and market changes, with 228 strongly agreeing, none agreeing, 84 undecided, and 24 disagreeing, with 25 strongly disagreeing, yielding a mean score of 4.06. This high mean score highlights a strong consensus on lean entrepreneurship's flexibility and responsiveness, though there are still some disagreements.

Test of Hypotheses

Hypothesis I

H01) AI-powered financial modeling does not significantly contribute to lean entrepreneurship among selected manufacturing firms in Nigeria.

Table 4.2 Correlations for Hypothesis I

			Lean Entrepreneurship
Spearman's rho	AI-powered Financial Modeling	Correlation Coefficient	.845**
		Sig. (2-tailed)	.000
		N	361

Source: SPSS V. 25 Analysis Output (2025)

The test of Hypothesis I, which posits that AI-powered financial modeling does not significantly contribute to lean entrepreneurship among selected manufacturing firms in Nigeria, shows a Spearman's rho correlation coefficient of 0.845 with a significance level of 0.000. This high correlation coefficient indicates a strong positive relationship between AI-powered financial modeling and lean entrepreneurship, suggesting that as the use of AI in financial modeling increases, so does the effectiveness of lean entrepreneurship practices among the firms studied. The significance value (p-value) of 0.000, which is well below the conventional threshold of 0.05, confirms that this relationship is statistically significant. Therefore, the null hypothesis (H01) is rejected, supporting the conclusion that AI-powered financial modeling significantly contributes to lean entrepreneurship in the context of Nigerian manufacturing firms. Therefore, AI-powered financial modeling significantly and positively contributes to lean entrepreneurship among selected manufacturing firms in Nigeria (Spearman's rho = 0.845; p-value of 0.000).

Hypothesis II

H02) AI-powered market research does not significantly influence lean entrepreneurship among selected manufacturing firms in Nigeria.

Table 4.3 Correlations for Hypothesis II

			Lean Entrepreneurship
Spearman's rho	AI-powered Market Research	Correlation Coefficient	.852**
		Sig. (2-tailed)	.000
		N	361

Source: SPSS V. 25 Analysis Output (2025)

In the test of Hypothesis II, which asserts that AI-powered market research does not significantly influence lean entrepreneurship among selected manufacturing firms in Nigeria, the correlation analysis yields a Spearman's rho correlation coefficient of 0.852, with a significance level of 0.000. This result demonstrates a very strong positive relationship between AI-powered market research and lean entrepreneurship, indicating that increased use of AI in market research is associated with more effective lean entrepreneurship practices. The p-value of 0.000 reinforces the statistical significance of this correlation, underscoring that the influence of AI-powered market research on lean entrepreneurship is not due to random chance. Consequently, the null hypothesis (H02) is also rejected, affirming that AI-powered market research has a significant positive impact on lean entrepreneurship among the manufacturing firms studied. Therefore, AI-powered market research significantly and positively influences lean entrepreneurship among selected manufacturing firms in Nigeria (Spearman's rho = 0.852; p-value of 0.000).

Discussion of Findings

The finding that AI-powered financial modeling significantly and positively contributes to lean entrepreneurship among selected manufacturing firms in Nigeria aligns with several studies that have examined the role of AI in enhancing financial decision-making and operational efficiency. For instance, Ale, Daniyan, Aderoba, and Adediran (2024) highlighted the impact of AI in predictive maintenance, demonstrating how AI-driven financial tools can optimize resource allocation and reduce waste, which are essential principles of lean entrepreneurship. Similarly, Chalmers, MacKenzie, and Carter (2021) discussed how AI can augment financial planning by automating complex modeling tasks, thereby enabling entrepreneurs to make more informed and timely decisions. These studies support the notion that AI-powered financial modeling not only streamlines financial operations but also contributes to the lean principles of reducing inefficiencies and maximizing value creation. However, some scholars, like Sharma (2019), argue that while AI enhances financial decision-making, its integration into lean entrepreneurship can be challenging due to the high costs and technical expertise required, potentially limiting its accessibility to smaller firms.

The finding that AI-powered market research significantly and positively influences lean entrepreneurship among selected manufacturing firms in Nigeria is corroborated by research that underscores the role of AI in providing deep hints into market trends and consumer behavior, which are crucial for lean entrepreneurship. Raneri, Lecron, Hermans, and Fouss (2023) demonstrated how AI-based predictive tools could enhance the “build-measure-learn” cycle in lean startup methodologies, leading to more precise and cost-effective market entry strategies. Similarly, Pfau and Rimpp (2021) emphasized the role of AI in refining market research processes by analyzing large datasets to identify market opportunities with higher accuracy and speed, thus supporting the lean objective of minimizing waste in resource allocation. Nonetheless, Chalmers, MacKenzie, and Carter (2021) caution that while AI can significantly improve market research, there is a risk of over-reliance on AI-generated data, which could lead to a reduction in the innovative and intuitive aspects of entrepreneurship, potentially stifling creativity and adaptability in rapidly changing markets.

Conclusion and Recommendations

Manufacturing firms in Nigeria that fully embrace Artificial Intelligence (AI) into their operations have an edge towards aligning this integration with lean entrepreneurship principles. This synergy enables these firms to optimize their production processes, reduce waste, and enhance productivity, ultimately leading to increased competitiveness both domestically and internationally. By leveraging AI, firms would be able to make data-driven decisions, predict market trends, and respond swiftly to customer demands, all while minimizing operational costs. This would foster an environment of continuous improvement, where innovation thrives, and businesses are agile enough to adapt to the rapidly changing global market dynamics. Thus, Nigerian manufacturing firms would not only meet global standards but also become leaders in efficient, sustainable, and innovative production. In conclusion, the strategic adoption of AI and lean entrepreneurship principles could provide the impetus needed for the manufacturing sector to achieve sustained growth and competitiveness.

For the finding that AI-powered financial modeling significantly and positively contributes to lean entrepreneurship among selected manufacturing firms in Nigeria, it is recommended that manufacturing firms in Nigeria should invest in AI-driven financial modeling tools to enhance their financial decision-making processes. This investment will enable firms to optimize resource allocation, reduce waste, and improve operational efficiency, which are essential for adopting lean entrepreneurship practices effectively.

For the finding that AI-powered market research significantly and positively influences lean entrepreneurship among selected manufacturing firms in Nigeria, it is recommended that marketing and research departments within Nigerian manufacturing firms should integrate AI-powered market research tools into their strategies. By doing so, these departments will gain deeper hints into market trends and consumer behavior, allowing them to make data-driven decisions that support lean entrepreneurship objectives, such as minimizing resource waste and maximizing market opportunities.

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