Vol. 7, No. 1, April 2026, hal. 19-29

Jurnal Computer Science and Information Technology (CoSciTech)

p-ISSN: 2723-567X
e-ISSN: 2723-5661

http://ejurnal.umri.ac.id/index.php/coscitech/index

Optimization of Backpropagation Algorithms for Enhancing Market Prediction Accuracy in Emerging Industries

Syaharuddin
syaharuddin.ntb@gmail.com

[1]Department of Mathematics Education, FKIP, Universitas Muhammadiyah Mataram, Indonesia

Diterima: | Direvisi: | Disetujui:

Abstract

This research aims to systematically review and analyze the application of backpropagation algorithms in data-driven business market prediction, focusing on emerging industries. Using the Systematic Literature Review (SLR) method, this study examined research articles from the Dimensions and Scopus databases published over the last 10 years. The analysis synthesizes findings related to the effectiveness, challenges, and potential advancements of Backpropagation in improving market prediction accuracy. The results reveal that backpropagation models, particularly LSTM and MLP have shown significant promise in various sectors, including financial forecasting, customer behavior analysis, and sales prediction. However, challenges such as overfitting, high computational costs, and the integration of real-world market complexities remain. The study emphasizes the need for continuous optimization of these models, as well as improvements in data quality and computational efficiency. This research contributes valuable insights for enhancing predictive models in business market forecasting and offers directions for future studies to further refine the use of backpropagation in addressing market prediction challenges.

Keywords: Backpropagation, Business Market, Forecasting, Machine Learning.

1. Introduction

Market prediction plays a pivotal role in modern business decision-making, serving as a cornerstone for informed strategies and effective operations [1]. In an increasingly competitive and dynamic market environment, the ability to forecast future trends and demands with precision has become indispensable for organizations aiming to maintain a competitive edge. Accurate market prediction enables businesses to anticipate changes in consumer behavior, economic conditions, and industry developments, thereby facilitating strategic planning and resource optimization [2]. Furthermore, it allows companies to mitigate risks by identifying potential challenges and opportunities ahead of time, ensuring resilience in the face of uncertainty. The integration of predictive analytics into decision-making processes not only enhances operational efficiency but also empowers organizations to allocate resources more effectively, capitalizing on emerging market opportunities and safeguarding long-term growth [3].

In the era of digital transformation, data has become a vital resource for enhancing market prediction accuracy [4]. The availability of vast amounts of structured and unstructured data, generated from diverse sources such as social media, online transactions, and economic reports, has revolutionized the field of forecasting. Unlike traditional methods that often relied on limited historical data and static models, data-driven approaches leverage advanced computational techniques to uncover complex patterns and relationships within datasets [5]. These methods enable businesses to analyze trends in real-time, providing timely insights into market dynamics and consumer preferences. By harnessing the power of data, organizations can move beyond intuition-based decision-making, embracing a more empirical and evidence-based approach [6]. This transition has not only improved the precision of market predictions but also expanded their applicability across industries, highlighting the critical role of data in driving informed and impactful business strategies.

Backpropagation is a fundamental algorithm in machine learning, particularly for training artificial neural networks (ANNs). It operates by calculating the gradient of the loss function with respect to each weight by applying the chain rule, allowing for efficient error correction through iterative updates. This process optimizes predictive models by minimizing the difference between predicted and actual outputs, thus enhancing model accuracy. Backpropagation computes the error at the output layer and propagates it backward through the network to update weights. It employs gradient descent to adjust weights, reducing the loss function iteratively until convergence is achieved [7]. The algorithm demonstrates versatility in various applications, including image recognition and time series prediction. Additionally, recent studies have explored hybrid methods, such as combining backpropagation with particle swarm optimization to enhance performance and avoid local minima [8]. While backpropagation is powerful, it can be limited by local optima during weight initialization. Alternative methods, like predictive coding, offer biologically plausible approaches that may circumvent some of these limitations, suggesting a potential for more robust learning mechanisms [9].

Backpropagation, a key algorithm in training artificial neural networks (ANNs), plays a crucial role in business market prediction by processing diverse data types, such as historical sales, customer behavior, and economic indicators. This enhances the accuracy of market forecasts and has proven effective across various sectors, demonstrating its versatility. In financial markets, backpropagation is used for stock price prediction, where models can achieve over 98% accuracy, significantly aiding investors in decision-making [10]. It is also utilized for pattern recognition, where neural networks identify complex financial patterns that traditional methods may overlook, thus improving investment strategies [11]. In customer behavior analysis, backpropagation is applied to predict telecom churn, with an accuracy of 82.12%, helping companies retain at-risk customers [12]. Furthermore, in sales forecasting, ANNs process large datasets, such as bike sales records, to identify trends and make accurate sales predictions, surpassing the limitations of traditional methods [13]. However, despite its effectiveness, it is important to recognize the limitations of backpropagation, such as the need for substantial data and computational resources, which may not be feasible for all businesses.

Backpropagation is a widely used algorithm in neural networks for business market prediction; however, it faces several challenges and limitations. Key issues include overfitting, high computational resource demands, and the complexity of integrating real-world market dynamics into predictive models. Overfitting occurs when a model learns the training data too well, resulting in poor generalization to new data, which is particularly problematic in financial predictions where market conditions can shift unexpectedly [14]. To mitigate overfitting, techniques such as reducing model complexity and employing regularization methods have been suggested, which can improve out-of-sample predictions [15]. Moreover, backpropagation requires significant computational resources, especially when using deep neural networks with numerous parameters, leading to increased costs and longer training times, which may be unfeasible for smaller firms [16]. Additionally, accurately modeling real-world market dynamics is challenging due to the unpredictable nature of financial markets, with traditional models often failing to capture the nuances of market behavior, resulting in inaccurate predictions. While backpropagation offers powerful predictive capabilities, its limitations highlight the need for careful consideration and adaptation to ensure its effective application in business market predictions.

Despite the widespread application of backpropagation in business market prediction, there are notable gaps in the existing literature, particularly regarding its targeted use for specific market segments and prediction tasks. While backpropagation has demonstrated effectiveness in general market forecasting, there is limited research that explores its tailored application to niche markets or specific business domains such as financial markets, telecom, and retail. Furthermore, while hybrid methods combining backpropagation with other optimization techniques have been studied, there is still a lack of comprehensive reviews that consolidate these findings, compare their effectiveness, and identify the most promising hybrid models. Additionally, the integration of real-world market dynamics and the challenge of mitigating issues such as overfitting and high computational demands remain underexplored in the context of market prediction. This study aims to fill these gaps by conducting a systematic review that not only consolidates existing knowledge but also identifies trends, limitations, and opportunities for future research. By doing so, it seeks to provide valuable insights into the current state of backpropagation in business market prediction and highlight areas that warrant further exploration to enhance its practical application and effectiveness.

The purpose of this study is to systematically review and analyze the application of backpropagation in data-driven business market prediction, with a focus on evaluating its effectiveness, identifying challenges, and exploring its potential to enhance forecasting accuracy across various business sectors. By synthesizing existing literature, this research aims to provide a comprehensive understanding of how backpropagation has been utilized to improve market predictions, particularly in areas such as financial forecasting, customer behavior analysis, and sales forecasting. Additionally, this study seeks to examine the limitations and gaps in the current application of backpropagation, such as issues related to overfitting, computational demands, and the integration of real-world market dynamics. Ultimately, the findings will offer insights into the strengths and weaknesses of backpropagation-based models and propose directions for future research to optimize its use in business market prediction.

2. Method

This research is a qualitative study employing the Systematic Literature Review (SLR) approach. This method is used to identify, evaluate, and interpret all relevant research findings regarding the application of backpropagation in data-driven business market prediction. The SLR approach enables researchers to systematically collect and analyze data from various relevant sources, providing a comprehensive understanding of the topic under study. The data in this study were sourced from the Dimensions database (https://app.dimensions.ai) and Scopus (https://www.scopus.com) with a publication interval of the last 10 years to ensure the inclusion of current and relevant studies related to backpropagation and its applications in business market prediction.

Data eligibility criteria in this study were established to ensure that only high-quality and relevant literature was analyzed. The criteria include (1) scientific articles published in reputable national and international journals; (2) studies specifically discussing the application of backpropagation in business market prediction or related fields such as machine learning and neural networks in business contexts; (3) publications from the last 10 years (2014–2024); and (4) articles available in full text and written in English. The research procedure is detailed in Figure 1.

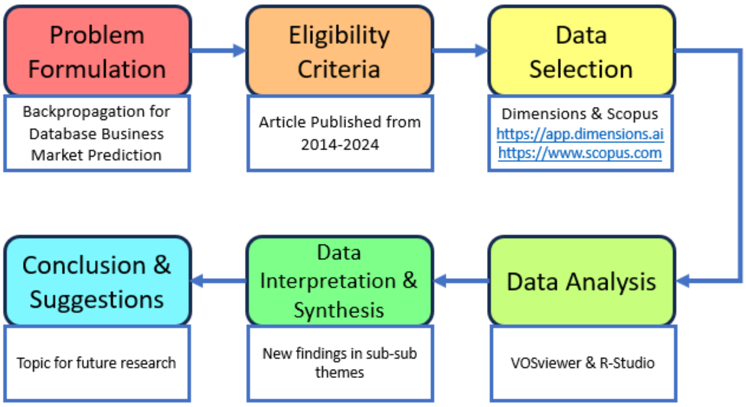

Figure 1. Research procedures

Figure 1 shows that this research was conducted in several stages, namely problem formulation, determining eligibility criteria, data selection, data analysis, data interpretation and synthesis, and drawing conclusions. The problem formulation stage was crucial to define the scope of the study, focusing on the use of backpropagation in data-driven business market prediction. Eligibility criteria were determined to filter data that fit the topic with relevant keywords such as "backpropagation," "business market prediction," "neural networks," and "machine learning for market forecasting." Following this, data were collected from the Dimensions and Scopus databases, with a filter applied for publications from 2014 to 2024.

The selected data were then imported into bibliometric tools such as VOSviewer to visualize keyword relationships and thematic clusters in the field, and R-Studio was utilized for descriptive statistical analysis. The use of these tools facilitated an in-depth exploration of data trends, including the frequency of themes, the evolution of methodologies, and the identification of research gaps. The results of the bibliometric and statistical analyses were then interpreted to provide insights into the effectiveness, challenges, and potential advancements of backpropagation in business market prediction.

Finally, the findings from the data analysis and synthesis were used to formulate key conclusions and implications for both theoretical understanding and practical applications. The researcher also outlined potential directions for future research to address identified gaps and further improve the use of backpropagation in market prediction. These conclusions are expected to contribute to advancing the field of data-driven business forecasting and the development of more effective predictive models.

3. Result and Discussion

3.1. Results of Data Selection

The results of the search conducted in the indexer database found a total of 24,988 data related to the research topic. From the data selection process, 5,120 articles were found to be relevant and met the eligibility criteria. Of these, 4,409 were journal articles, and 711 were proceeding articles. The distribution of data based on the year of publication can be seen in Figure 2, which shows the development of the number of studies related to curriculum management of modern Islamic boarding schools over the last 10 years.

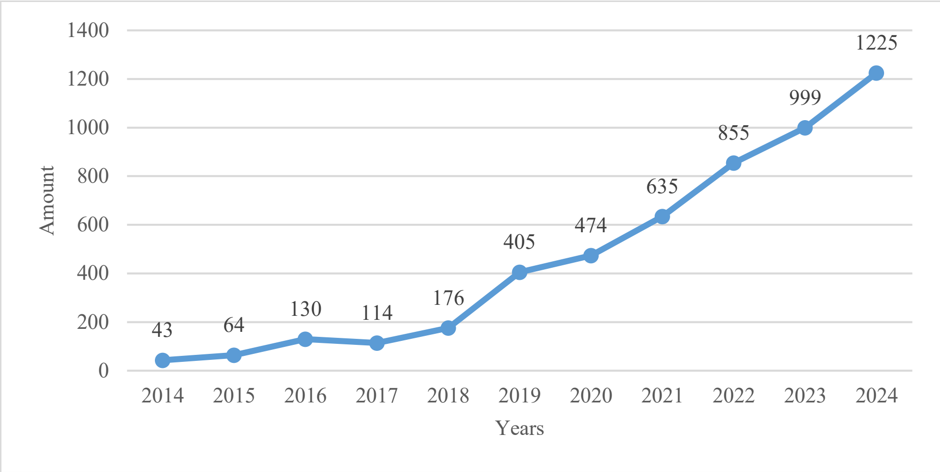

Figure 2. Publications in each year

Figure 2 illustrates the trend in the number of publications related to Backpropagation for Data-Based Business Market Prediction from 2014 to 2024. The data shows a steady growth in research interest over the past decade. In 2014, the number of publications was relatively low, with only 43 studies. This figure gradually increased, reaching 130 publications by 2016. A slight decline occurred in 2017, with 114 publications, before the trend resumed its upward trajectory in 2018 with 176 publications.

A notable surge began in 2019, where the number of publications increased significantly to 405, nearly doubling in 2020 with 474 publications. This upward momentum continued in 2021 and 2022, reaching 635 and 855 publications, respectively. The peak was observed in 2024, with 1,225 publications, reflecting a growing recognition of the importance of backpropagation techniques in data-driven market prediction. This trend highlights the increasing role of machine learning and backpropagation algorithms in advancing market prediction accuracy and supporting data-based business decision-making.

3.2. Distribution of Research in Several Countries

Furthermore, researchers explored the distribution of publications and collaborations across countries in the field of Backpropagation for Data-Based Business Market Prediction. Figure 3 illustrates that this research topic has garnered significant attention globally, with collaborations observed among various countries such as the United States, China, India, Australia, Germany, and the United Kingdom. The map highlights the interconnectedness of research networks, where countries with advanced technological capabilities, such as the United States and China, play a central role in driving research and fostering collaborations with other nations. This international collaboration reflects the increasing importance of leveraging backpropagation and machine learning in addressing global business challenges.

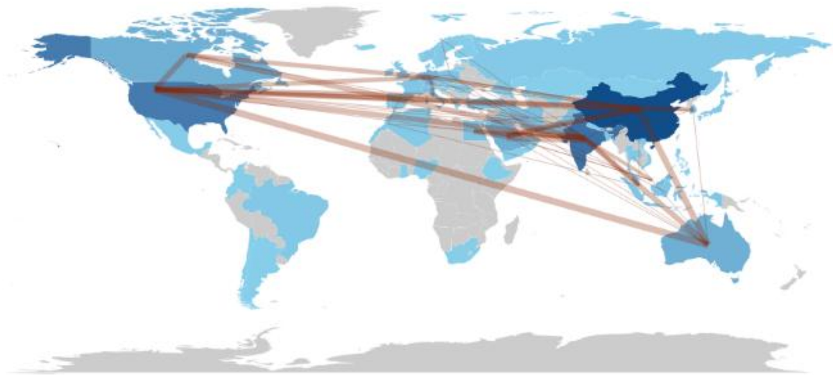

Figure 3. Countries' Collaboration World Map

Figure 3 also indicates that the high level of collaboration between countries determines the visibility and impact of publications in the field of Backpropagation for Data-Based Business Market Prediction. Countries with significant collaboration networks, such as the United States, China, and India, contribute not only to the quantity of publications but also to the depth of their impact, as these works are often cited and reviewed extensively by researchers worldwide. The interconnectedness among countries enhances the opportunity for innovative methodologies and findings to be widely disseminated, thereby amplifying their contribution to advancements in business market predictions [17].

Furthermore, Table 1 highlights the ten countries with the highest number of citations related to research on Backpropagation for Data-Based Business Market Prediction. Switzerland leads with the most significant total citations, reaching 14,396, and an exceptionally high average citation per article of 2,056.60, demonstrating the substantial impact and quality of research originating from this country. Other countries, such as Canada and the United Kingdom, also show notable contributions, with average citations per article of 118.30 and 308.00, respectively. These figures suggest that while some countries produce fewer publications, the quality and influence of their research are highly impactful, solidifying their role as key contributors to the global body of knowledge in this field.

Table 1. Most Cited Countries

No	Country	Total Citation	Average Article Citations
1.	SWITZERLAND	14396	2.056,60
2.	CANADA	2957	118,30
3.	CHINA	2903	29,60
4.	INDIA	2526	42,10
5.	MALAYSIA	2302	230,20
6.	GERMANY	2089	160,70
7.	USA	1713	46,30
8.	UNITED KINGDOM	924	308,00
9.	AUSTRALIA	760	31,70
10	ITALY	618	68,70

Furthermore, Switzerland and the United Kingdom stand out with remarkably high average citations per article of 2,056.60 and 308.00, respectively, indicating that research from these countries tends to garner significant individual attention from the global academic community (publication count distribution can be seen in Figure 3). This suggests that while some countries like China and India have higher publication productivity, the quality or relevance of articles from Switzerland and the United Kingdom is perceived as more impactful on average by researchers worldwide.

Additionally, Table 1 shows the comparative total citations and average article citations across the top 10 countries contributing to the field of Backpropagation for Data-Based Business Market Prediction. While countries such as Canada and Germany have relatively fewer total citations compared to Switzerland, their average citations per article of 118.30 and 160.70 reflect the substantial academic influence of their research. This data highlights the importance of not only publication quantity but also the depth and quality of research outputs in driving advancements in this field.

Figure 4 illustrates the progression of research publications over the past decade in five countries: the USA, Canada, China, Australia, and India, focusing on the topic of Backpropagation for Data-Based Business Market Prediction. The figure highlights significant differences in publication trends across these countries, reflecting variations in interest and contributions to this research field. While some countries demonstrate a rapid growth trajectory, others exhibit a slower, steadier development over time. This data provides a comprehensive overview of how different regions have participated in advancing research on this topic.

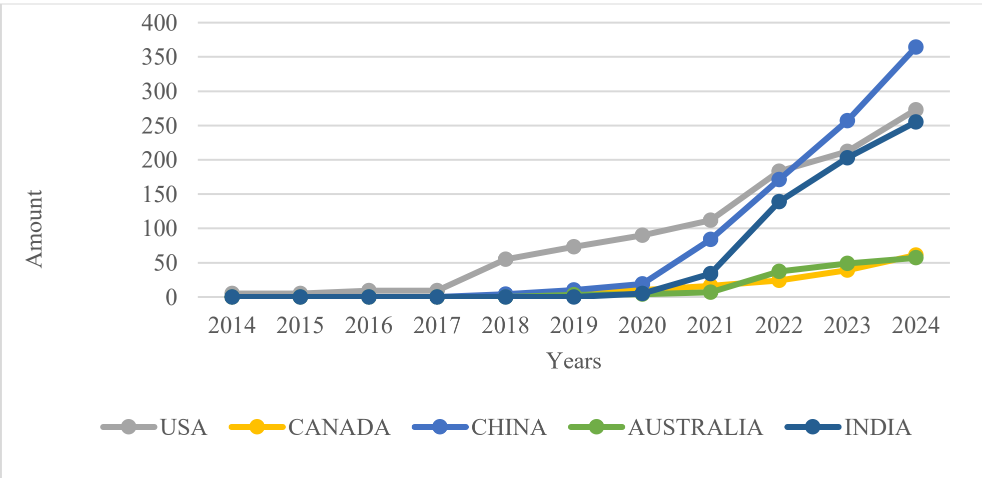

Figure 4. Countries' Production over Time

https://doi.org/10.37859/coscitech.v7i1.11122

Figure 4 shows the trend of research publications in the USA, Canada, China, Australia, and India over the past 10 years. The USA demonstrates consistent growth, particularly after 2018, reaching 273 publications in 2024, which signifies its leadership in this field. Similarly, China shows a remarkable surge starting from 2019, peaking with 364 publications in 2024, surpassing all other countries in the latest year. India, while starting later in 2020, has also shown significant growth, reaching 255 publications in 2024. On the other hand, Canada and Australia display relatively low publication counts throughout the decade, with Canada gradually increasing to 61 publications in 2024 and Australia maintaining a minimal but steady interest, with fewer than 50 publications annually. These trends suggest a dynamic and growing interest in Backpropagation for Data-Based Business Market Prediction globally, with China and the USA emerging as the most dominant contributors in recent years.

3.3. Network Visualization of Data

Furthermore, researchers visualized all research results using VOSviewer to see the research variables and the relationship between variables. The visualization results are as shown in Figure 5.

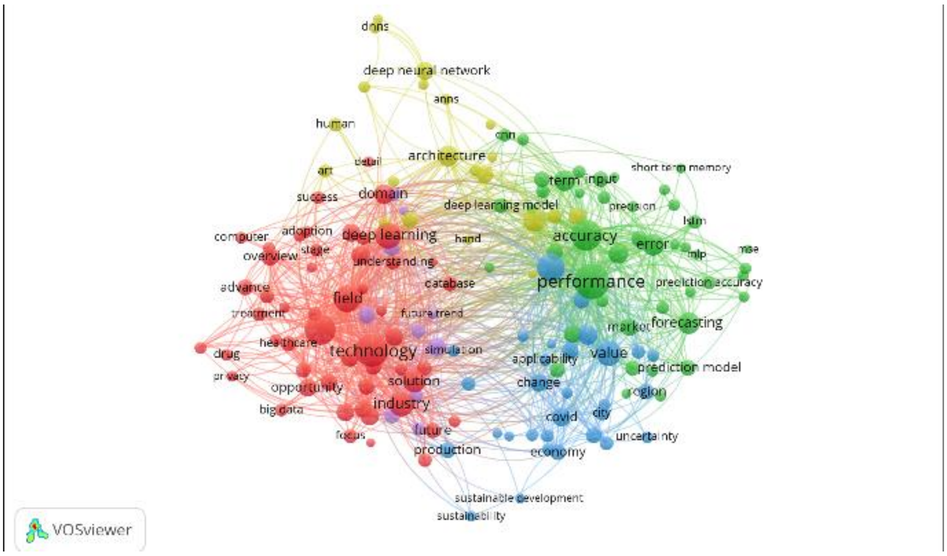

Figure 5. Network visualization of modern boarding school curriculum management.

Figure 5 is a network visualization of all variables studied over the past 10 years and depicts four different color clusters: green, red, yellow, and blue. The interpretation is as follows. The red cluster predominantly emphasizes the integration of technology and practical applications in addressing real-world challenges. Keywords such as technology, field, deep learning, and industry are central to this group, reflecting the widespread utilization of technological advancements in various sectors. Research in this area often explores how cutting-edge technologies, such as deep learning, are implemented across industries like healthcare, big data analytics, and beyond. For instance, the application of deep learning in healthcare has revolutionized diagnostic accuracy and treatment personalization, while big data has facilitated the analysis of vast, complex datasets to extract actionable insights. This cluster highlights the significance of adopting technology not merely as a theoretical concept but as a transformative tool in solving practical problems. Moreover, the increasing reliance on these technologies underscores their pivotal role in enhancing operational efficiency, optimizing resource allocation, and driving innovation within industry-specific contexts.

The green cluster is centered on improving the performance and accuracy of predictive models, a crucial aspect of backpropagation and its applications in business market forecasting. Keywords such as accuracy, performance, prediction accuracy, and error underscore the focus on optimizing algorithms to achieve superior predictive capabilities. This emphasis is particularly relevant in addressing the inherent complexities of market dynamics, where accurate forecasting is essential for strategic decision-making. Advanced methods like Long Short-Term Memory (LSTM) networks and Multi-Layer Perceptrons (MLPs) are frequently employed to refine model performance. Researchers aim to minimize prediction errors by improving training efficiency and developing robust evaluation metrics. The outcomes of this research not only enhance the reliability of predictive systems but also contribute to their scalability, making them applicable across diverse market scenarios. The green cluster thus represents the intersection of technical precision and practical applicability, highlighting the critical importance of accuracy in achieving meaningful results.

The yellow cluster focuses on architectural innovations and technical components of predictive models. Keywords such as architecture, deep neural network, CNN, and ANNs suggest a strong emphasis on designing and developing advanced neural network structures. Research in this cluster delves into the optimization of neural network architectures to accommodate complex data patterns and improve model efficiency. Convolutional Neural Networks (CNNs) and Artificial Neural Networks (ANNs) are particularly prominent in this field, offering sophisticated approaches to data modeling and feature extraction. This focus on architecture underscores the necessity of tailoring predictive models to specific use cases, ensuring they are not only effective but also computationally efficient. By addressing challenges related to scalability, adaptability, and processing power, the yellow cluster highlights the ongoing evolution of neural network designs as integral to advancing predictive analytics.

The blue cluster addresses the economic value and sustainability of predictive technologies. Keywords such as value, economy, sustainability, and sustainable development indicate that this cluster extends beyond technical considerations to explore the broader implications of predictive models on economic and environmental systems. Research in this area emphasizes the dual goals of enhancing business efficiency and fostering long-term sustainability. For example, predictive models can be leveraged to optimize supply chains, reduce waste, and allocate resources more effectively, thereby contributing to sustainable economic growth. Additionally, this cluster underscores the role of predictive analytics in addressing global challenges such as climate change and resource scarcity by providing actionable insights for policy and decision-making. The blue cluster, therefore, integrates technological innovation with socio-economic priorities, demonstrating the potential of predictive technologies to drive both profitability and sustainability in modern business practices. Based on the interpretation of each cluster, the researcher can formulate several important points as a synthesis of the curriculum management of modern Islamic boarding schools as follows:

3.3.1 Utilization of Technology in Business Market Prediction (Red Cluster)

The application of advanced technologies, particularly deep learning and big data, has significantly transformed the ability to predict business market trends across various industries, facilitating the analysis of complex datasets, enhancing decision-making processes, and addressing practical challenges. Big data enables the analysis of vast and diverse datasets, crucial for understanding stock market trends through both technical and fundamental analyses [18], while automated methods are essential for processing the overwhelming volume of data, allowing businesses to identify emerging trends and make timely decisions [19]. Deep learning models, particularly Long Short-Term Memory (LSTM) networks, have shown high efficacy in predicting stock prices by analyzing historical data and technical indicators [20], enhancing prediction accuracy and assisting in developing effective trading strategies, although challenges remain in profitability validation and risk management. In sectors like healthcare and finance, big data analytics and machine learning are employed to derive insights from unstructured data, improving operational efficiency and innovation [21], while the COVID-19 pandemic has accelerated the adoption of mobile commerce, showcasing the need for intelligent analytics systems to navigate evolving market landscapes . Conversely, while advanced technologies offer substantial benefits, they also introduce complexities such as data privacy concerns and the potential for over-reliance on automated systems, which may lead to unforeseen risks in decision-making.

Advanced technologies like deep learning and big data are transforming various industries, including healthcare, sports, and education. In healthcare, artificial intelligence and deep learning can enhance randomized controlled trials by improving patient selection and generating more sensitive endpoints [22]. In sports, deep learning and data mining techniques have been applied to optimize swimming training, resulting in significant performance improvements [23]. The education sector has benefited from big data analytics and machine learning models to predict student performance and implement timely interventions, such as collaborative learning, to enhance academic outcomes [24]. As industries transition towards digitalization and Industry 4.0, continuous vocational training in skills like robotics, Internet of Things, and artificial intelligence is crucial for achieving various business results, including technical management, commercial management, and sustainable development [25].

The findings illustrate how advanced technologies, such as deep learning and big data, are revolutionizing business market predictions and expanding their applicability across diverse sectors. In financial markets, technologies like Long Short-Term Memory (LSTM) networks demonstrate their ability to process historical data and technical indicators effectively, enabling businesses to forecast trends and enhance decision-making strategies. Simultaneously, big data analytics allow industries to analyze vast datasets, identifying actionable patterns and improving operational efficiencies in healthcare, finance, and education. The acceleration of intelligent analytics adoption during the COVID-19 pandemic further highlights the technology's adaptability to evolving market challenges, while other sectors like sports and education leverage deep learning to optimize processes and outcomes. These findings emphasize that technological integration drives innovation, precision, and competitiveness across industries, even as challenges like data privacy and over-reliance persist.

3.3.2 Improving Accuracy and Performance of Backpropagation Models (Green Cluster)

Efforts to enhance the accuracy and reliability of backpropagation models for market predictions have increasingly focused on advanced techniques such as Long Short-Term Memory (LSTM) networks and Multi-Layer Perceptrons (MLP), which leverage deep learning capabilities to optimize prediction performance, reduce errors, and achieve greater precision in forecasting stock market trends. LSTM networks are particularly effective for time series data, making them suitable for stock price predictions, as they have been shown to outperform traditional models by capturing complex temporal patterns in financial data [26], and a study demonstrated that LSTM combined with hybrid momentum indicators significantly improved prediction accuracy for stock market indices and volatility (Kyoung & Hongjoong, 2019). Multi-Layer Perceptrons (MLP) have also been utilized, with research indicating that they can effectively forecast stock market returns through backpropagation algorithms [28], and the integration of MLP with Self-Optimizing Maps (SOM) has been shown to enhance convergence and improve forecasting accuracy compared to linear regression models. Various metrics such as Mean Squared Error (MSE), Root Mean Squared Error (RMSE), and Pearson's correlation coefficient are employed to evaluate the performance of these models, with LSTM and CNN-LSTM models achieving high R-squared values in predictions [29]. While LSTM and MLP models have shown promising results, challenges remain in addressing the inherent volatility and nonlinearity of financial markets, and continuous advancements in model architectures and training techniques are essential for further improving prediction accuracy.

Recent studies have explored advanced machine learning techniques to enhance market predictions and optimize model performance. Seyyed Soroosh Firoozabadi et al. (2024) evaluated LSTM, XGBoost, and SVM models for crude oil return rate predictions, finding SVM to be superior during the COVID-19 pandemic. Multi-Layer Perceptron (MLP) was employed by Rivan Nur Ihsan et al. (2022) to predict basic commodity prices on major holidays in Indonesia, demonstrating varying levels of accuracy across different products. Jooh Lee & He-Boong Kwon (2021) utilized a two-stage regression-neural network approach to investigate the synergistic effects of R&D and exports on firm performance in US manufacturing industries. Their findings revealed positive impacts on market-based performance, particularly in high-tech firms. Lufeng Hu et al. (2015) developed a backpropagation artificial neural network (BP-ANN) model to predict paraquat concentrations after hemoperfusion treatment, achieving high prediction accuracy ($R = 0.9977$).

The studies demonstrate a significant evolution in the application of deep learning techniques, particularly Long Short-Term Memory (LSTM) networks and Multi-Layer Perceptrons (MLP), to improve the accuracy and performance of backpropagation models for market predictions. LSTM networks have proven effective in capturing complex temporal patterns in stock price data, outperforming traditional models and improving prediction accuracy, particularly when combined with momentum indicators. MLP, on the other hand, has been successfully used to forecast stock market returns and commodities prices, showcasing its ability to optimize predictions when integrated with techniques like Self-Optimizing Maps (SOM). Furthermore, various performance metrics such as Mean Squared Error (MSE) and Root Mean Squared Error (RMSE) reveal that LSTM and CNN-LSTM models have achieved high R-squared values, indicating improved prediction accuracy. Recent research also explores additional machine learning techniques such as XGBoost and Support Vector Machines (SVM), with studies like Firoozabadi revealing SVM's superiority in specific market conditions, such as during the COVID-19 pandemic.

3.3.3 Architectural Innovations in Neural Network-Based Predictive Models (Yellow Cluster)

The development and refinement of neural network architectures, particularly Convolutional Neural Networks (CNNs) and Artificial Neural Networks (ANNs), play a crucial role in enhancing predictive modeling by improving accuracy, scalability, and efficiency, enabling these models to process complex data effectively. Minimal adjustments in CNN architectures can yield significant performance improvements, as demonstrated by the new approach to receptive field analysis, which predicts unproductive layers before training [33], and this method has successfully enhanced parameter efficiency across various state-of-the-art CNN models, achieving new performance benchmarks on datasets like ImageNet1K. The Teaching-Learning-Based Optimization (TLBO) method has been introduced to design optimal CNN architectures, achieving high accuracy with lower complexity [34], and this approach allows for the creation of CNN models tailored to specific datasets, enhancing their predictive capabilities. Deep neural architectures have shown promise in healthcare, particularly in diagnosing neurodegenerative diseases like Parkinson's, by integrating medical knowledge with advanced image analysis techniques [35], and these systems demonstrate high accuracy and adaptability, showcasing the potential of deep learning in critical applications. While the advancements in neural network architectures are promising, challenges such as high computational costs and the need for extensive training data remain significant hurdles in their widespread adoption [36].

Recent advancements in neural network architectures have significantly improved predictive modeling in various domains. Convolutional Long Short-Term Memory networks have shown promise in classifying emotional speech content, predicting group dynamics with high accuracy [37]. Artificial Neural Networks (ANNs) have been enhanced through sequential sensitivity analysis and randomized training, improving efficiency for high-dimensional data processing [38]. Innovative approaches like randomized hashing have drastically reduced computational costs in deep learning, maintaining accuracy while using only 5% of total multiplications [39]. In medical image segmentation, a high-performance deep learning model combining key elements from U-Net-based architectures has been proposed, aiming to create an automated diagnostic tool for various cancers [40]. These developments demonstrate the ongoing refinement of neural network architectures to enhance accuracy, scalability, and efficiency across different applications.

The research highlights significant innovations in neural network architectures, particularly Convolutional Neural Networks (CNNs) and Artificial Neural Networks (ANNs), which have played a vital role in improving the accuracy, scalability, and efficiency of predictive models. Minimal adjustments in CNN designs, such as receptive field analysis, have resulted in considerable performance gains, enhancing parameter efficiency and setting new benchmarks in datasets like ImageNet1K. Techniques like the Teaching-Learning-Based Optimization (TLBO) method have been introduced to optimize CNN architectures, resulting in high accuracy and lower complexity. Additionally, deep neural networks have shown promising applications in healthcare, such as diagnosing neurodegenerative diseases, and in emotional speech classification, achieving high accuracy in predicting group dynamics. Furthermore, advancements in computational efficiency, such as randomized hashing techniques, have reduced computational costs while maintaining accuracy. The research also emphasizes the potential of neural networks in automating medical diagnostics, such as in cancer detection through advanced image segmentation methods.

3.3.4 Economic Value and Sustainability in Market Prediction Implementation (Blue Cluster)

Predictive models significantly influence economic value creation and sustainability by optimizing resource use, enhancing supply chain efficiency, and aligning with socio-economic and environmental goals, facilitating informed decision-making and driving sustainable business outcomes. Predictive models enable firms to analyze resource consumption patterns, leading to reduced waste and cost savings [41], while also employing predictive analytics to forecast demand and manage inventory more effectively, resulting in streamlined operations and improved profitability [42]. Engaging in sustainable supply chain practices not only enhances corporate reputation but also leads to increased sales and reduced financial risks [43]. Furthermore, predictive models support corporate social responsibility (CSR) initiatives by assisting organizations in assessing the financial stability of non-profit partners, fostering collaboration that supports sustainable initiatives [44], and AI tools simplify sustainability reporting, making it easier for businesses to communicate their environmental impact and compliance with regulations (Lahti et al., 2023). While predictive models offer substantial benefits, there is a risk of over-reliance on data-driven decisions, which may overlook qualitative factors essential for holistic sustainability, making it crucial to balance quantitative insights with qualitative assessments for achieving comprehensive sustainable outcomes.

Predictive models and digital technologies can significantly impact economic value creation and sustainability across various sectors. In manufacturing, smart technologies can reduce costs, increase revenues, and create positive externalities [46]. The synergistic effect of R&D and exports on firm performance, particularly in high-tech industries, demonstrates the potential for economic growth through innovation (Lee & Kwon, 2023). In healthcare, implementing machine learning models for surgical case duration prediction can improve resource utilization, patient wait times, and overall efficiency [48]. However, educating future business leaders about sustainability and fragility issues remains challenging. A study on teaching interventions in sustainability education showed limited impact on students' understanding of complex sustainability concepts, highlighting the need for more effective educational approaches [49]. These findings underscore the importance of aligning predictive analytics with long-term socio-economic and environmental priorities for sustainable business outcomes.

The research illustrates the significant impact of predictive models on economic value creation and sustainability by enhancing resource optimization, improving supply chain management, and aligning with socio-economic and environmental goals. Predictive analytics facilitates resource consumption analysis, reducing waste and cost, while forecasting demand and optimizing inventory management enhances operational efficiency and profitability. In addition, sustainable practices within supply chains not only improve corporate reputation but also increase sales and reduce financial risks. Moreover, predictive models support Corporate Social Responsibility (CSR) initiatives by aiding in financial stability assessments of non-profit partners, promoting sustainable collaborations. AI tools simplify sustainability reporting, improving businesses' ability to communicate their environmental impact and compliance. However, an over-reliance on data-driven decision-making could overlook qualitative factors crucial for achieving holistic sustainability. Additionally, the integration of predictive models in various sectors like manufacturing and healthcare further demonstrates their potential to drive economic value and sustainability, while also highlighting challenges in effectively educating future leaders on sustainability concepts.

4. Conclusion

This study provides a comprehensive review and analysis of the application of backpropagation algorithms in data-driven market prediction, highlighting its effectiveness, challenges, and potential for improving forecasting accuracy in various business sectors. The findings reveal that backpropagation, particularly through advanced deep learning models like LSTM and MLP, has significantly enhanced prediction accuracy in financial forecasting, customer behavior analysis, and sales forecasting. These models capture complex patterns within market data, enabling businesses to make more informed decisions. However, challenges such as market volatility, model nonlinearity, and high computational demands persist, necessitating continuous refinement in model architecture and training methodologies. Additionally, while techniques like XGBoost and SVM have shown promise in addressing some of these challenges, integrating multiple machine learning methods may provide further improvements in prediction reliability.

Despite the advancements in backpropagation and neural network architectures, the widespread adoption of these models remains hindered by the need for large volumes of high-quality data and the computational burden they impose. The integration of innovative methods such as receptive field analysis and randomized hashing has improved efficiency, but these innovations are not universally applicable. Furthermore, the over-reliance on quantitative data in predictive models raises concerns about neglecting qualitative factors essential for sustainable and holistic decision-making. To effectively optimize backpropagation algorithms for market prediction, future research should focus on overcoming the computational and data quality barriers, while also considering the broader socio-economic and environmental implications of technology adoption.

In conclusion, while backpropagation algorithms and deep learning models show great potential in enhancing market prediction accuracy, a balanced and adaptive approach is essential. Incorporating ethical considerations, skill development, and interdisciplinary strategies will be crucial for overcoming existing challenges and achieving sustainable, long-term business outcomes. The future of backpropagation in market prediction lies in its continuous optimization, integration with other machine learning techniques, and its alignment with sustainable business practices.

References

[1] T. Rahman, "Data-Driven Decision Making in Modern Business Management," *Rev. J. Manag. Soc. Pract.*, vol. 1, no. 4, pp. 56–72, 2024.

[2] A. Gupta and P. Agarwal, "Enhancing sales forecasting accuracy through integrated enterprise resource planning and customer relationship management using artificial intelligence," in *2024 3rd International Conference on Artificial Intelligence For Internet of Things (AIIoT)*, IEEE, 2024, pp. 1–6.

[3] A. O. Adewusi, U. I. Okoli, E. Adaga, T. Olorunsogo, O. F. Asuzu, and D. O. Daraojimba, "Business intelligence in the era of big data: a review of analytical tools and competitive advantage," *Comput. Sci. IT Res. J.*, vol. 5, no. 2, pp. 415–431, 2024.

[4] U. S. Nwabekee, O. Y. Abdul-Azeez, E. E. Agu, and T. Ignatius, "Digital transformation in marketing strategies: The role of data analytics and CRM tools," *Int. J. Front. Res. Sci. Technol.*, vol. 3, no. 2, pp. 55–72, 2024.

[5] H. Rahmanifard and I. Gates, "A Comprehensive review of data-driven approaches for forecasting production from unconventional reservoirs: best practices and future directions," *Artif. Intell. Rev.*, vol. 57, no. 8, p. 213, 2024.

[6] L. B. Benjamin, P. Amajuoyi, and K. B. Adeusi, "Leveraging data analytics for informed product development from conception to launch," *GSC Adv. Res. Rev.*, vol. 19, no. 2, pp. 230–248, 2024.

[7] M. V Narkhede, P. P. Bartakke, and M. S. Sutaone, "A review on weight initialization strategies for neural networks," *Artif. Intell. Rev.*, vol. 55, no. 1, pp. 291–322, 2022.

[8] I. M. Widiartha, A. A. N. Gunawan, E. R. N. A. Sanjaya, and K. Sari, "A hybrid method of backpropagation and particle swarm optimization for enhancing accuracy performance," *Curr. J. Appl. Sci. Technol.*, vol. 42, no. 6, pp. 10–18, 2023, doi: 10.9734/cjast/2023/v42i64072.

[9] R. Kanai, Y. Komura, S. Shipp, and K. Friston, "Cerebral hierarchies: predictive processing, precision and the pulvinar," *Philos. Trans. R. Soc. B Biol. Sci.*, vol. 370, no. 1668, p. 20140169, 2015.

[10] E. Riyanto, "Peramalan Harga Saham Menggunakan Jaringan Syaraf Tiruan Secara Supervised Learning Dengan Algoritma Backpropagation," *J. Inform. Upgris*, vol. 3, no. 2, 2017.

[11] J. K. Jaiswal and R. Das, "Application of artificial neural networks with backpropagation technique in the financial data," in *IOP Conference Series: Materials Science and Engineering*, 2017. doi: 10.1088/1757-899X/263/4/042139.

[12] J. Xu, J. Liu, T. Yao, and Y. Li, "Prediction and big data impact analysis of telecom churn by backpropagation neural network algorithm from the perspective of business model," *Big Data*, vol. 11, no. 5, pp. 355–368, 2023.

[13] D. Kurniawan, M. R. Sanjaya, and E. L. Ruskan, "Implementation of a neural network approach for predicting sales profit," *AJRCoS*, vol. 16, no. 3, pp. 65–75, 2023, doi: 10.9734/ajrcos/2023/v16i3346.

[14] J. Schmidt, M. R. G. Marques, S. Botti, and M. A. L. Marques, "Recent advances and applications of machine learning in solid-state materials science," *npj Comput. Mater.*, vol. 5, no. 1, p. 83, 2019.

[15] M. M. Bejani and M. Ghatee, "A systematic review on overfitting control in shallow and deep neural networks," *Artif. Intell. Rev.*, vol. 54, no. 8, pp. 6391–6438, 2021.

[16] J. B. Heaton, "Quantitative investing and the limits of (deep) learning from financial data," *SSRN Electron. J.*, 2018, doi: 10.2139/ssrn.3133110.

[17] J. Naranjo Perez, L. Zhang, and X. Li, "A scientometric review on green manufacturing systems for small and medium sized enterprises (SMEs)," in *6th International Conference on Advanced Research Methods and Analytics (CARMA 2024)*, Editorial Universitat Politècnica de València, 2024, pp. 62–70.

[18] V. S. Yadav and A. R. Singh, "Use of blockchain to solve select issues of Indian farmers," in *AIP Conference Proceedings*, AIP Publishing, 2019.

[19] O. Saritas, P. Bakhtin, I. Kuzminov, and E. Khabirova, "Big data augmentated business trend identification: the case of mobile commerce," *Scientometrics*, vol. 126, no. 2, pp. 1553–1579, 2021.

[20] A. W. Li and G. S. Bastos, "Stock market forecasting using deep learning and technical analysis: a systematic review," *IEEE access*, vol. 8, pp. 185232–185242, 2020.

[21] J. E. Raja, P. M. Kumar, M. K. Vincet, M. Ramachandran, and V. Prasanth, "A Review on Various Data Prediction Technologies," *Data Anal. Artif. Intell.*, vol. 2, no. 1, pp. 53–58, 2022.

[22] C. S. Lee and A. Y. Lee, "How artificial intelligence can transform randomized controlled trials," *Transl. Vis. Sci. Technol.*, vol. 9, no. 2, p. 9, 2020.

[23] S. Liu and S. Sun, "[Retracted] Optimizing the Training Mode of Swimmers Based on Deep Learning and Data Mining Technology," *Wirel. Commun. Mob. Comput.*, vol. 2022, no. 1, p. 1694833, 2022.

[24] A. Rafique *et al.*, "Integrating learning analytics and collaborative learning for improving student's academic performance," *IEEE Access*, vol. 9, pp. 167812–167826, 2021.

[25] J. R. Aranda, I. Campos, C. Cosculluela, J. San Martin, and C. De Pablos, "Continuous vocational training in response to the challenge of industry 4.0: Required skills and business results," *J. Ind. Eng. Manag.*, vol. 16, no. 2, pp. 319–341, 2023.

[26] J. Jung and J. Kim, "A performance analysis by adjusting learning methods in stock price prediction model using LSTM," *J. Digit. Converg.*, vol. 18, no. 11, pp. 259–266, 2020.

[27] M. Kyoung-Sook and K. I. M. Hongjoong, "Performance of deep learning in prediction of stock market volatility.," *Econ. Comput. Econ. Cybern. Stud. Res.*, vol. 53, no. 2, 2019.

[28] A. H. Moghaddam, M. H. Moghaddam, and M. Esfandyari, "Stock market index prediction using artificial neural network," *J. Econ. Financ. Adm. Sci.*, vol. 21, no. 41, pp. 89–93, 2016.

[29] T. H. H. Aldhyani and A. Alzahrani, "Framework for predicting and modeling stock market prices based on deep learning algorithms," *Electronics*, vol. 11, no. 19, p. 3149, 2022.

[30] S. S. Firoozabadi, M. Ansari, and F. Vasheghanifarahani, "Crude Oil Trend Prediction During COVID-19: Machine Learning with Randomized Search and Bayesian Optimization," *Eur. J. Bus. Manag. Res.*, vol. 9, no. 3, pp. 6–13, 2024.

[31] R. N. Ihsan, S. Saadah, and G. S. Wulandari, "Prediction of Basic Material Prices on Major Holidays Using Multi-Layer Perceptron," *J. Media Inform. Budidarma*, vol. 6, no. 1, pp. 443–452, 2022.

[32] L. Hu *et al.*, "Clearance rate and BP-ANN model in paraquat poisoned patients treated with hemoperfusion," *Biomed Res. Int.*, vol. 2015, no. 1, p. 298253, 2015.

[33] M. L. Richter and C. Pal, "Receptive field refinement for convolutional neural networks reliably improves predictive performance," *arXiv Prepr. arXiv2211.14487*, 2022.

[34] K. M. Ang *et al.*, "Optimal design of convolutional neural network architectures using teaching–learning-based optimization for image classification," *Symmetry (Basel).*, vol. 14, no. 11, p. 2323, 2022.

[35] D. Kollias, A. Tagaris, A. Stafylopatis, S. Kollias, and G. Tagaris, "Deep neural architectures for prediction in healthcare," *Complex Intell. Syst.*, vol. 4,

pp. 119–131, 2018.

[36] S. F. Ahmed *et al.*, "Deep learning modelling techniques: current progress, applications, advantages, and challenges," *Artif. Intell. Rev.*, vol. 56, no. 11, pp. 13521–13617, 2023.

[37] M. M. Morgan, I. Bhattacharya, R. J. Radke, and J. Braasch, "Classifying the emotional speech content of participants in group meetings using convolutional long short-term memory network," *J. Acoust. Soc. Am.*, vol. 149, no. 2, pp. 885–894, 2021.

[38] S. Ganguly, M. Dutta, T. Ghosh, M. A. Ahmed, and B. Maitra, "Systemic approach to revamp unsignalized intersections using multi-criteria decision making: a comparison of alternative solutions.," *Adv. Transp. Stud.*, vol. 57, 2022.

[39] R. Spring and A. Shrivastava, "Scalable and sustainable deep learning via randomized hashing," in *Proceedings of the 23rd ACM SIGKDD International Conference on Knowledge Discovery and Data Mining*, 2017, pp. 445–454.

[40] A. R. Luca *et al.*, "Designing a high-performance deep learning theoretical model for biomedical image segmentation by using key elements of the latest U-Net-Based architectures," *J. Comput. Commun.*, vol. 9, no. 07, pp. 8–20, 2021.

[41] G. Yang, X. Li, T. Yu, S. Wu, and Y. Liu, "A New Model of Environmental-Economic Coordination Prediction Using Credible Neural Network Integration and Big Data Analysis," *Secur. Commun. Networks*, vol. 2022, no. 1, p. 3454821, 2022.

[42] W. M. Patrick, P. I. Anselemo, R. Ronoh, and S. Mbugua, "Impact of predictive analytics of big data in supply chain management on decision-Making," *Int. J. Sci. Res. Comput. Sci. Eng. Inf. Technol*, vol. 3307, pp. 225–238, 2022.

[43] R. N. Mefford, "The economic value of a sustainable supply chain," *Bus. Soc. Rev.*, vol. 116, no. 1, pp. 109–143, 2011.

[44] J. Mazanec and V. Bartosova, "Prediction model as sustainability tool for assessing financial status of non-profit organizations in the Slovak Republic," *Sustainability*, vol. 13, no. 17, p. 9721, 2021.

[45] M. Salo-Lahti, M. Ranta, and H. Haapio, "AI Tools for Sustainability–Actionable Information for both Humans and Machines," in *Rechtsinformatik als Methodenwissenschaft des Rechts: Legal Informatics as Science of Legal Methods. Proceedings of the 26th International Legal Informatics Symposium IRIS*, 2023, pp. 199–209.

[46] S. V Ilkevich, "Strategy of digital transformation of industrial enterprises: The effects of the introduction of smart manufacturing technologies," *Strateg. Decis. risk Manag.*, vol. 13, no. 3, pp. 210–225, 2022.

[47] J. Lee and H.-B. Kwon, "Synergistic effect of R&D and exports on performance in US manufacturing industries: high-tech vs low-tech," *J. Model. Manag.*, vol. 18, no. 2, pp. 343–371, 2023.

[48] C. T. Strömblad *et al.*, "Effect of a predictive model on planned surgical duration accuracy, patient wait time, and use of presurgical resources: a randomized clinical trial," *JAMA Surg.*, vol. 156, no. 4, pp. 315–321, 2021.

[49] J. J. Platje, A. Styś, M. Will, and W. Lambrechts, "The impact of teaching interventions in education for sustainable development–an experimental case study," *Cent. Eur. Rev. Econ. Manag.*, vol. 6, no. 3, pp. 69–86, 2022.