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Deep learning techniques business performance optimization in micro, small, and medium-sized enterprises: systematic review

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ABSTRACT

The application of deep learning is transforming how micro, small, and medium-sized enterprises (MSMEs) operate. By using data-driven insights, these firms overcome traditional analytical limitations and improve decision-making. This study explores factors influencing deep learning adoption in MSMEs, identifies effective strategies, and compares performance between companies that implement these methods and those that do not. The objective is to analyze the impact of deep learning on optimizing the performance of MSMEs. The methodology consisted of a scientific review following the preferred reporting items for systematic reviews and meta-analyses (PRISMA) system and a bibliometric analysis to map international contributions. The results show that techniques such as recurrent neural networks (RNNs), long short-term memory (LSTM) networks, transformers, and deep reinforcement learning (DRL) are crucial for marketing strategy prediction, customer experience personalization, and inventory management, leading to better return on investment (ROI), loyalty, and efficiency. Despite the potential benefits, there's still no enough research on how small businesses with limited resources use these methods and deal with issues like poor infrastructure and data access. Deep learning is essential for MSMEs' sustainability and competitiveness, even if there are challenges.

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1. INTRODUCTION

Micro, small, and medium-sized enterprises (MSMEs) represent a central component of economic development, contributing significantly to employment generation and regional productivity worldwide [1]. In Ecuador, these enterprises are crucial for boosting national output via innovation, employment generation, and enhanced production efficiency. They encompass a wide range of economic activities, including commerce, agriculture, forestry, manufacturing, construction, and services such as transportation and communications [2]. Legally, MSMEs are recognized under specific regulations that include both formally registered companies and individual entrepreneurs. Enhancing the performance of these enterprises is vital to stimulate economic growth and labor stability. Therefore, strengthening small and medium-sized firms can generate better employment opportunities, reduce regional economic disparities, and promote competitiveness in international markets, particularly in exports and workforce quality [3].

Research by Schmitt [4], notes that deep learning has been increasingly integrated into industrial environments and is now recognized as a key enabler for intelligent decision-making. Despite its potential, its incorporation into business analytics remains limited, mainly because of the exaggerated expectations and the lack of specialized roles. Research by Islam *et al.* [5], explain that during the forward propagation phase, a neural network determines its output based on the assigned weight values applied to the input data. In this process, training samples are introduced into the system to adjust the network's internal parameters. This type of artificial neural network (ANN), known for its unidirectional information flow from input to output without feedback or closed loops is commonly applied in rapid-learning contexts and pattern recognition tasks due to its efficiency and simplicity.

Modular neural networks integrate various autonomous components working independently, helping shape the final outcome. Every network processes its own unique data and performs dedicated subtasks autonomously. In this model, the networks operate independently without exchanging signals to perform actions. The core advantage of modular neural networks is their ability to simplify computation by segmenting a large process into smaller, independent units [5], [6].

Long short-term memory (LSTM), a type of recurrent neural network (RNN), can remember past data to make future predictions [7], [8]. This model good for sequential data analysis like sales, inventory, or customer behavior over time. While Mughees *et al.* [9] indicate that the performance of the LSTM model was optimized by using a genetic algorithm to find an optimal number of layers and optimal time delays. An ANN consists of three layers (input layer, hidden layer, and output layer).

Deep reinforcement learning (DRL) brings significant algorithmic improvements, offering effective solutions for various complex decision-making and control issues [10], and is notable for its real-time optimization in dynamic pricing, resource allocation, and marketing strategies. DRL is unique for adapt and generalize well, used in robotics, planning, cyber-physical, and energy systems. Its challenges push Industry 4.0. [11].

A deep neural network (DNN) is a type of algorithm with multiple processing layers that can achieve outstanding results in complex applications. Since the prediction of customer churn is essentially a binary classification problem, DNNs serve as a powerful method to handle it [12]. Likewise, Benk *et al.* [13], indicate that DNNs have been utilized for both churn prediction and anticipating customer purchases.

The connection between customer orientation and organizational performance in MSMEs also assesses the probable impact of innovation orientation, market volatility, and competition on the level of consumer focus. Nevertheless, what matters most is improving return on investment (ROI), understood as the profit generated in proportion to the investment [14], [15].

This research looks at how deep learning boost MSMEs performance. It check important signs like work done, how well things run, customer handling, and money back from investment. Recent studies show deep learning boost MSMEs' competitiveness and sustainable growth by spotting trends, chances, and issues.

2. METHOD

A full study done on different systematic review methods like Kitchenham and preferred reporting items for systematic reviews and meta-analyses (PRISMA). Careful study of each method's features and use in different situations, review needs, and best tools for study quality check. PRISMA method chosen for better transparency and repeatability in systematic review reports.

The search strategy was meticulously designed to include keywords and subject headings related to the study's focus, ensuring a thorough and unbiased collection of relevant literature. Followed PRISMA framework principles for systematic reviews and meta-analysis [16]. Research studies were checked for fit with goals and methods, focusing on popular designs and how they connect to chosen variables. A thorough and critical review of the papers' method quality was done, based on set criteria for inclusion and exclusion. Also, a reason for choosing and combining articles was made to keep the review open and repeatable.

2.1. Research questions

The research technique that acts as a data filter was used, starting from the broadest to the most specific, i.e., the problem, intervention, comparison, objective (PICO) questions [17], [18]. The use of this technique to formulate the guiding research question towards the specific population is: In comparison with conventional approaches, what is the impact of deep learning applications on the business performance of MSMEs? Table 1 breaks down the specific sub-questions for each component of the PICO technique. The systematic search strategy for scientific literature of the PICO model is broken down in Table 2.

Table 1. Formulation of PICO questions

Code	Questions
P	What demographic and operational characteristics of MSMEs influence the adoption of deep learning techniques to improve their business performance?
I	What are the most effective deep learning techniques used by MSMEs to optimize their business performance compared to conventional approaches?
C	In what ways does the application of deep learning influence the business performance of MSMEs compared with traditional optimization approaches?
O	Which business performance indicators show significant improvements in MSMEs that implement deep learning techniques compared to those that do not?

Table 2. Systematic search strategy for scientific literature

Factor	Description	Search terms	Synonyms
Problem	MSMEs considered within the framework of business and commercial performance.	"Microenterprise", "Small business", "Medium-sized business", "MSMEs"	“SMEs”, “micro company”, “small company”, “medium-sized company”
Intervention	Deep learning techniques applied to business performance optimization.	"Deep learning", "Artificial neural networks", "Convolutional neural networks"	"deep reinforcement learning", "deep neural architectures", "recurrent neural network"
Comparison	Traditional methods of optimizing business performance in MSMEs.	"Data analysis", "Data evaluation", "Data assessment"	"data review", "data investigation", “data study”
Objective	Business performance optimization indicators for MSMEs.	"Business performance", "Operating performance", "Economic performance"	"performance metrics", "business performance", "business effectiveness", "ROI"

2.2. Preparing database searches

A structured search query was developed to identify and retrieve studies addressing business performance optimization within MSMEs. This query was executed across major academic repositories, including Scopus and Web of Science, to ensure comprehensive coverage of relevant scientific literature:

("micro enterprise" OR "small enterprise" OR "medium enterprises" OR "micro business" OR "small business" OR "medium business" OR "micro company" OR "small company" OR "medium company" OR "SMEs" OR "Mipymes" OR "Company") AND (“Artificial Neural Networks” OR “ANNs” OR “Convolutional Neural Networks” OR “CNNs” OR “Recurrent Neural Networks” OR “RNNs” OR “Generative Adversarial Networks” OR “Gas” OR “Differentiable Memory Networks” OR “Dynamically Growing Neural Networks” OR “Autoencoders” OR “Graph Neural Networks” OR “GNNs)” OR “Deep Reinforcement Learning” OR “Deep Learning” OR “DL”) AND ("data analysis" OR "data evaluation" OR "data examination" OR "data investigation" OR "data study" OR "data assessment" OR "analysis") AND ("commercial performance" OR "business performance" OR "operational performance" OR "economic performance" OR "performance metrics" OR "business performance" OR "organizational performance" OR "corporate performance" OR "business effectiveness" OR "ROI" OR "sales growth" OR "revenue growth" OR "sales performance" OR "customer conversion" OR "customer conversion rate").

The designed search query enables an in-depth exploration of studies that address how deep learning methods contribute to improving the commercial performance of MSMEs. It supports the identification of relevant findings in current literature, focusing on implementation outcomes, influencing factors, and external conditions that shape the effectiveness and sustainability of these technologies in business environments.

2.3. Eligibility criteria

These inclusion and exclusion criteria ensure the relevance, accuracy, and applicability of the research in the context of MSMEs, serving as a solid foundation for analyzing the impact of deep learning models for business performance optimization, as shown in Table 3.

Table 3. Inclusion and exclusion criteria

Criteria	Code	Description
Inclusion	I1	Research covering different sectors (commerce, services, and manufacturing)
	I2	Studies that apply deep learning techniques to improve business decisions
	I3	Research that presents quantitative or qualitative data on the optimization of business performance
	I4	Articles that analyze the economic impact of the implementation of these techniques in MSMEs
Exclusion	E1	Research that does not use or mention deep learning techniques
	E2	Articles that do not present evidence of improved business performance or lack empirical data
	E3	Studies that are not directly related to the business performance of MSMEs
	E4	Articles were published more than 5 years ago

2.4. Sources of information

Choosing databases such as Scopus and Web of Science (WoS) to access data in scientific studies provides numerous advantages that make them indispensable for researchers. These databases offer a wide and updated coverage of studies in different areas, which allows us to find important works and assess the impact of the research (see Figure 1).

Figure 1. Databases and information sources consulted in the study

2.5. Article selection process

The article selection followed four stages: identification, pre-screening, selection, and inclusion. Articles were first located through a targeted search, then filtered by titles and abstracts. Consistent inclusion and exclusion criteria ensured methodological rigor. Finally, the remaining studies were reviewed in depth focusing on introduction, methods, and conclusions to determine their relevance for the qualitative synthes. Certain studies were chosen, identifying those articles that are likely to satisfy the requirements and that meet the conditions necessary to be accepted for research purposes, as explained in Figure 2.

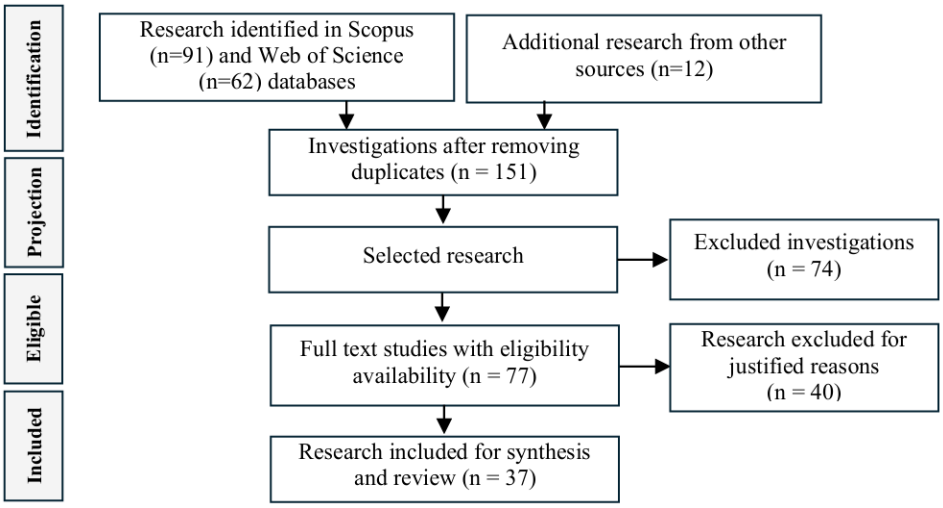

Figure 2. Flow diagram illustrating the article selection process

Among the 165 studies initially identified, 14 duplicates were removed, leaving 151 for preliminary review. After applying the exclusion criteria, 74 papers were discarded, and 77 proceeded to the inclusion assessment. During the final evaluation, 40 studies that failed to satisfy at least one inclusion condition were excluded. Consequently, 37 articles met all established requirements and were incorporated into the qualitative synthesis.

To achieve an objective and detailed classification of the selected articles, it has been decided to use an approach based on agglomerative hierarchical clustering. This technique is widely used in data analysis and machine learning, allows grouping elements into clusters, facilitating a deeper understanding of the behavior of large data sets [19]. Automatic clustering algorithm used for fair classification without bias. This method helps group docs by similarity using labels, avoiding subjective bias in sorting. Subsequently, an

agglomerative hierarchical clustering method based on Euclidean distance was applied to assess the similarity between documents. As a result, three main clusters were identified. An overview of each of them is presented (see Figure 3).

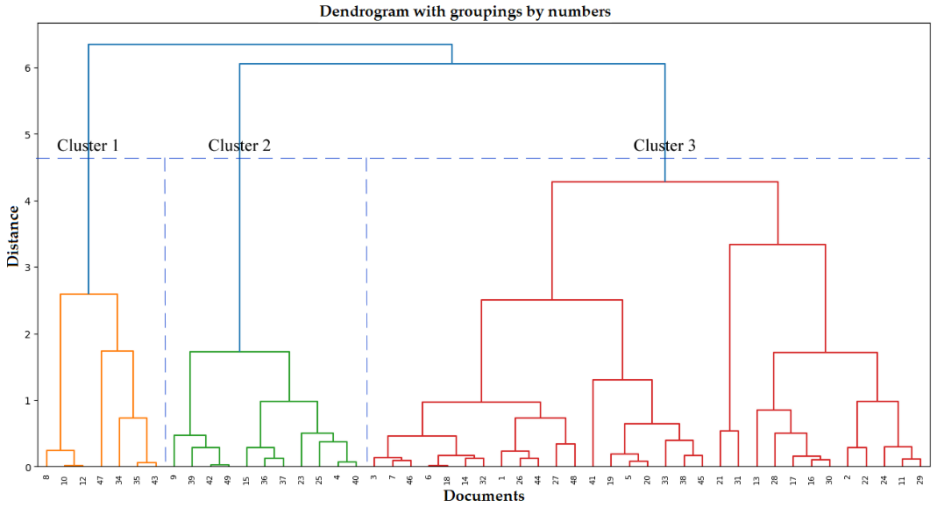

Figure 3. Hierarchical grouping of articles

Cluster 1: it is composed of terms related to the development and application of CNN, highlighting concepts such as convolution and neural network models, which reflect the mathematical foundations and architectures used in these networks. It includes advanced algorithms and classification techniques, such as support vector machines and random forests, essential for prediction and pattern analysis. In addition, it covers deep learning methods and neural networks, along with advanced artificial intelligence techniques, focused on data processing applications.

Cluster 2: it is composed of ANN applied to the optimization and improvement of business processes, with a focus on the analysis and management of large volumes of data (big data). Its main objective is to support decision-making in the business field and the evaluation of organizational performance. It includes key terms related to data mining and business management, such as business performance and economic performance. In addition, it integrates digital storage and data analytics, which are essential for the collection, storage, and analysis of information on a large scale.

Cluster 3: formed by business and organizational performance, this cluster encompasses terms related to the measurement and improvement of organizational performance, as well as the analysis of human and organizational factors that influence business success. The document encompasses themes of operational efficiency, human resource management, organizational effectiveness, and efficiency metrics, and it discusses the application of machine learning algorithms to enhance these areas, in addition to predictive analysis and performance metrics, which are.

3. RESULTS AND DISCUSSION

3.1. Results

Building on the main insights obtained from the systematic review, the next section discusses the research outcomes in relation to the formulated questions, emphasizing how they contribute to strengthening commercial performance optimization strategies within MSMEs.

A1: MSMEs' adoption of deep learning techniques depends on factors such as the size of the enterprise, with medium-sized companies generally better resourced; geographic location, influencing technological access; and the industry sector, with prominence in technology and e-commerce. The effectiveness of these techniques is operationally determined by digitalization, robust and accessible data, and an organizational culture committed to innovation and continuous improvement.

A2: DNNs are key among the deep learning approaches employed by MSMEs to optimize business performance, enabling the analysis of substantial datasets to customize strategies and forecast customer behavior; ANNs assist in classification and regression, fundamental to market segmentation and predicting sales, and RNNs together with LSTM are ideal for analyzing sequential datasets, such as purchase sequences

and temporal variations. Furthermore, DRL demonstrates significant value in optimizing dynamic decisions like pricing, inventory, and marketing strategies, delivering superior performance and responsiveness over traditional approaches.

A3: MSMEs using deep learning outperform traditional methods by predicting market trends, customizing offers, and cutting costs. In contrast, traditional methods are often reactive, with limited scope for optimizing processes and improving customer experience.

A4: MSMEs that implement deep learning show notable improvements in indicators such as ROI, revenue growth, conversion rate, and customer loyalty. In addition, they achieve greater reduction in operating costs and market penetration, standing out from those that do not adopt these advanced techniques, which tend to stagnate in more basic and less efficient management models.

Table 4 presents the research questions and the number of articles available to effectively answer them. This analysis allows us to identify the bibliographical support, highlighting the areas with the greatest academic support and those that may require further exploration.

Table 4. Questions and number of articles

Questions	Scientific article
What demographic and operational characteristics of MSMEs influence the adoption of deep learning techniques to improve their business performance?	The articles mentioned above reveal the adoption of deep learning techniques in MSMEs: [20]-[28].
What are the most effective deep learning techniques used by MSMEs to optimize their business performance compared to conventional approaches?	The most effective deep learning techniques in MSMEs that outperform traditional methods in accuracy and capacity are detailed in the following articles: [6], [29]-[39].
In what ways do deep learning techniques influence the business performance of MSMEs compared with traditional optimization approaches?	A set of articles provides insight into MSMEs using deep learning to significantly improve their business performance: [40]-[50].
Which business performance indicators show significant improvements in MSMEs that implement deep learning techniques compared to those that do not?	The articles mentioned above point us to the adoption of deep learning to improve business performance: [51]-[60].

Figure 4 is a term cloud related to machine learning, artificial intelligence, and data science; in this group, the most prominent due to their size are "deep learning", "machine learning", "neural networks", "long short-term memory", "sentiment analysis" and "forecasting". Other relevant expressions are "artificial neural network", "regression analysis", "decision trees", "support vector machines", and "convolutional neural networks". This visualization aims to emphasize the main themes and emerging research areas within machine learning and its practical implementations.

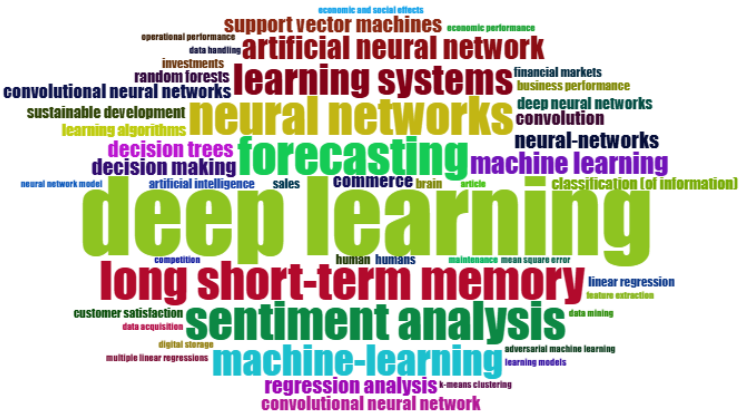

Figure 4. Keywords

3.1.1. Bibliometric analysis

Current trends focus on digital marketing personalization and the use of deep learning models to improve customer service and the effectiveness of marketing campaigns. This analysis provides a solid foundation for future research and highlights the importance of continuing to explore this dynamic and relevant field of study. The generated network visualization shows several interconnected keyword clusters,

highlighting the main areas of research in the field of study. For the bibliometric analysis, the search results of the Scopus academic database were taken into account.

Top nodes: larger nodes represent key terms such as “machine learning,” “artificial intelligence,” “deep learning forecasting,” and “decision making” These terms appear more frequently and have a greater impact on the network. Meaningful connections: links between nodes show concept relationships Deep learning and digital marketing have strong link and relevance for MSMEs (see Figure 5).

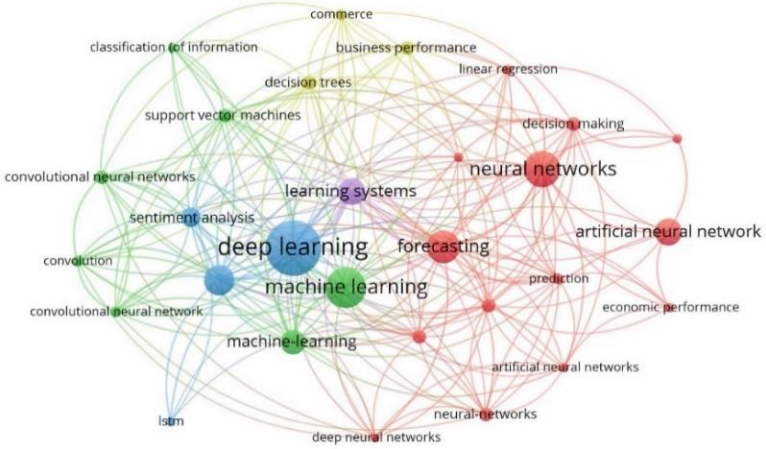

Figure 5. VOSviewer (network visualization) map result

Overlay visualization show key trends in deep learning model use in MSME digital marketing these results give a full picture of study field evolution, spotlighting new areas and trends important for future research (see Figure 6).

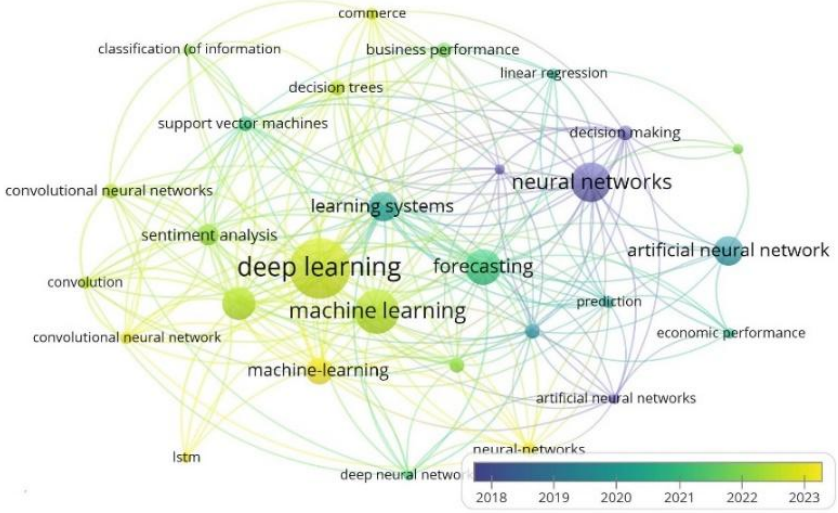

Figure 6. VOSviewer map result (overlay visualization)

Current trends aim to customize business performance and use deep learning for better customer interaction. This analysis give strong base for future research and show need to keep exploring this important and changing field.

Bibliometrics create a map showing countries' scientific input in MSMEs and deep learning for business success. This map show where big science papers come from, spotting countries with most science work. It also allows observing country alliances, simplifying identification of key research networks and global actors in this field (see Figure 7).

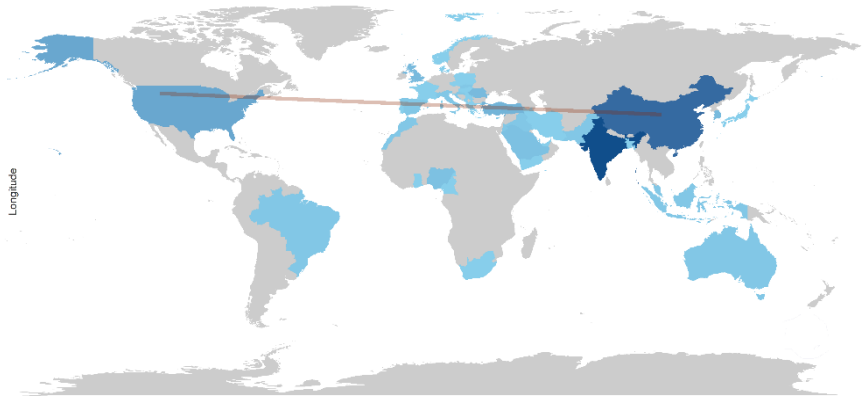

Figure 7. Bibliometrix map result (country map)

3.1.2. Algorithm model of the proposal

The model for deep learning in MSMEs has a clear method, starting with gathering data and cleaning it, making sure it's good quality. Then, the most suitable model is selected, considering options such as RNN, LSTM, RNA or DRL, depending on the specific business objectives, and the model is trained with the previously processed data. After training, model checked with ROI and business metrics to confirm its effectiveness before business use. Lastly, a constant monitoring and tweaking process is set up, with regular updates and retraining to handle new problems and keep performance at its best. This method help MSMEs make long-term gains in efficiency and business success (see Figure 8).

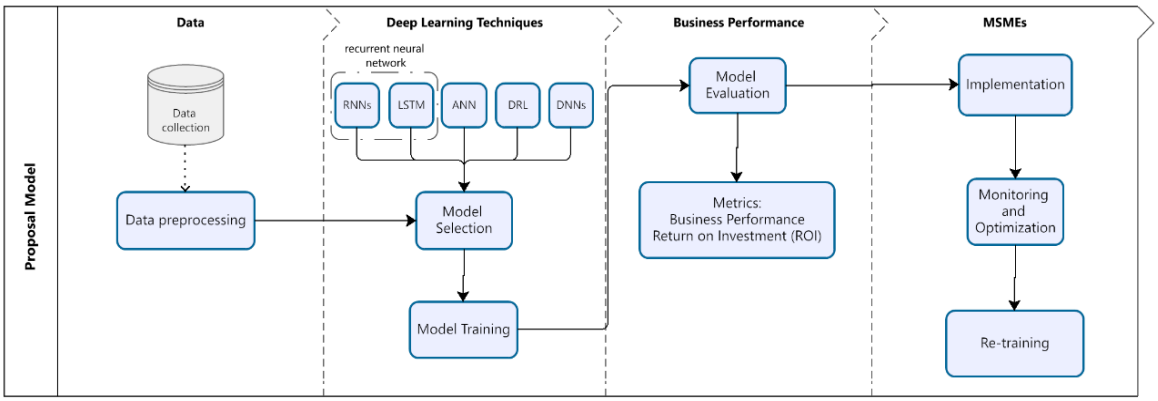

Figure 8. Proposal template

3.2. Discussion

The integration of deep learning into MSMEs is revolutionizing traditional business approaches, allowing data-informed optimization that strengthens performance and competitive advantage. Enterprises with limited resources and high competition historically face operational and strategic hurdles, but advanced technologies provide a path to overcome them. Yet, adoption depends on critical factors such as organizational size, digital readiness, culture, and data access, widening the gap between technologically advanced and traditional companies.

Factors such as the size of the enterprise, degree of digitalization, cultural receptiveness to innovation, and the quality and accessibility of data largely dictate whether firms can fully leverage these technologies. As a result, some companies accelerate using deep learning, while others remain bound to traditional practices, unable to achieve predictive precision or sustainable growth.

DNNs, ANNs, and RNNs with LSTM represent advanced deep learning techniques that excel at trend prediction, marketing optimization, and customer personalization. Alongside these, DRL offers significant benefits in dynamic decision-making and managing key operational areas such as pricing and inventory control.

Companies that integrate these technologies see measurable improvements in critical business outcomes such as ROI, conversion rates, and customer loyalty. In comparison, those relying on traditional approaches face limitations in prediction capabilities and scaling operations.

Adopting deep learning is crucial not only for technology itself, but also for developing complementary capabilities such as data governance, employee training, and strategic partnerships that enable effective integration. Without addressing these enablers, adoption may be uneven, potentially widening gaps between firms instead of closing them. Thus, the challenge extends beyond technology to organizational and cultural dimensions, requiring a holistic strategy that aligns digital transformation with the specific realities of MSMEs.

4. CONCLUSION

The evolution of neural networks, including modular, recurrent, and deep architectures, together with reinforcement learning, is transforming the way organizations handle complex challenges. These tools go beyond process optimization, facilitating decisions based on data. For MSMEs, they can significantly improve business results by identifying opportunities, enhancing efficiency, and customizing strategies. As a result. Deep learning therefore appears as a strategic friend for MSMEs as they strive for sustainability and competitiveness in a corporate setting.

The success of these instruments is driven by factors including digital readiness, data quality, and a culture receptive to innovation. Though deep learning is positioned as a crucial catalyst for the sustainable development, there are difficulties with execution including staff training and initial investment. MSMEs' modernity and competitiveness in the economy today. This emphasizes how important it is for these businesses to include cutting-edge technologies into their business plans to fully realize their potential and guarantee their future expansion.

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AUTHOR CONTRIBUTIONS STATEMENT

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

DATA AVAILABILITY

No new data were generated or analyzed in this systematic review of the literature. All data are from published sources.

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