

AI-Powered Foreign Exchange Risk Management: Comparing Traditional vs. Machine Learning Approaches

Authors:

¹Ejiroghene Amanda

Onohwakpo,

²Ugochi Linda

Onyeonufo

Affiliation:

^{1,2}Independent

Researcher.

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Abstract

Foreign exchange (FX) risk management has evolved significantly with the advent of artificial intelligence and machine learning technologies. This research paper examined the comparative effectiveness of traditional risk management approaches versus modern machine learning methodologies in managing foreign exchange exposure. Through analysis of risk measurement techniques, hedging strategies, and predictive capabilities, this study demonstrates that while traditional approaches provide foundational risk management frameworks, machine learning methods offer enhanced accuracy in volatility prediction, dynamic hedging optimization, and real-time risk assessment. The findings suggest that hybrid approaches combining traditional financial theory with machine learning capabilities provide optimal risk management outcomes for organizations operating in global markets.

Keywords: Foreign exchange risk, machine learning, artificial intelligence, risk management, hedging strategies, volatility prediction

1. Introduction

The evolution of currency risk management through the utilization of AI has revolutionized conventional methods, boasting an added value in terms of efficiency, accuracy and response. The AI Systems utilizes auto-learning algorithms to evaluate enormous data sets at a rapid pace, consequently allowing for real-time decision-making levels beyond conventional norms (Aziz & Dowling, 2019). The systems can recognize patterns and correlations within market movements, resulting in enhancing the accuracy of risk forecasting (Mashrur et al., 2020). Apart from that, the adaptability for volatile financial markets allows continuous learning, which enhances performance in the

long run considerably (Akande, 2024). Nonetheless, there are limitations. The AI algorithms are susceptible to relying on the quality of input data; Low or biased data can result in faulty predictions Addy et al. (2024). Besides, the black-box nature of certain AI algorithms has the potential to limit transparency and understandability between users, which undermines confidence in decision-making processes. Thus, despite AI-Rome enhanced risk management, cautious implementation and supervision are still inevitable to combat weaknesses.

Foreign exchange risk is one of the most important issues confronting foreign market investors, financial institutions, and multinational companies.

The intrinsic volatility of exchange rates can affect in a material way financial performance, cash flows, and general business operations. Conventional foreign exchange risk management has been based on established financial theory, statistical modelling, and conventional hedging instruments. Machine learning and artificial intelligence technologies have brought in new visions of even more advanced and responsive risk management frameworks. The \$6.6 trillion-a-day global foreign exchange market, as reported by the Bank for International Settlements, continues to be exposed to growing volatility propelled by geopolitical, economic uncertainty, and sentiment extremes. Such an environment calls for more sophisticated risk management tools with capabilities to handle big data and respond to dynamic market conditions at high speed.

The aim of this study is to present an exhaustive comparison between traditional foreign exchange risk management methods and new machine learning strategies, contrasting respective advantages and drawbacks and real-world applications in modern financial markets.

2. Literature Review

2.1 Traditional Foreign Exchange Risk Management

FX currency risk management is at the heart of financial markets and conventional practices which have long remained the signature. Hedging under derivatives, term contracts and options have been extensively utilized to counterbalance the risk of monetary volatility. But given evolving financial markets, these practices have the drawbacks of being rigid and having the ability to react slowly to market movement Aziz and Dowling (2019).

Conversely, automatic learning methods have been the game-changers in FX risk management. Research indicates that machine learning methods have the capacity to scan large datasets and extract patterns so that more responsive and knowledgeable decision making is possible (El Hajj & Hammoud, 2023a; Mashrur et al., 2020). For instance, Akande (2024) writes about the use of deep learning in financial risk management, highlighting its capacity to enhance predictive accuracy in uncertain environments.

Secondly, Ahmad et al. (2024) take into consideration direct applications of AI in managing currency risk in cash management, citing its improved performance over conventional techniques. The incorporation of AI represents a direction towards advanced risk

management techniques, with much better outcomes for market participants (El Hajj & Hammoud, 2023a). As such, whereas conventional techniques are viable, the efficacy of AI techniques makes the argument for development of currency risk management compelling.

Conventional foreign exchange risk management has been rooted in proven financial theory and experience developed over years. Jorion (1997) listed the main ways of measuring and managing currency exposure: translation exposure, transaction exposure, and economic exposure. These methods depend primarily on statistical measures such as Value at Risk (VaR), calculation of standard deviation, and correlation analysis to estimate potential loss.

Historical analysis remains the conventional method in FX risk management that depends mostly on using historical data analysis, taking a belief that historical price movement and volatility trends are a good source to utilize in forecasting risks. Shapiro (2013) emphasized hedging methods through derivative products in the form of forward contracts, options, and swaps for reducing currency exposure. They are generally put into practice under predefined rules and manual decision-making.

2.2 Machine Learning in Financial Risk Management

The FX risk management human capital has thus far been based on strategies like diversification and coverage, whose effectiveness was typically complemented by no adaptability and accuracy demanded in today's financial settings. Akande (2024) brings to light the significance of the addition of artificial intelligence (AI) and deep learning algorithms for tuning financial cadres of risks management as a shift in paradigm towards other data driven practices. Conversely, Aziz and Dowling (2019) note the capacity of machine learning (ML) to improve the accuracy of risk measures such that organizations can better detect and react to changes in the market.

The effectiveness of artificial intelligence techniques, however, relies on their capability to process huge sets of data at fast speed. El Hajj and Hammoud (2023b) present an in-depth analysis of artificial intelligence use in financial markets and unveil that machine learning algorithms can outperform conventional practices regarding predictive accuracy. In cash management, Ahmad et al. (2024) reveal the means through which artificial intelligence tools enable more sophisticated approaches in managing FX risks and thereby enhanced operational efficiency as a whole. Also, Mashrur et al. (2020) elaborate on the several ML applications in financial risk management, short of agreement on the value of such technologies.

Lastly, Abikoye et al. (2024) look at the nexus of risk management processes in Fintech and conventional financial institutions, indicating that future mitigation of FX risk is heavily reliant on the implementation of AI-based solutions. The changing trends imply that although conventional practices remain indispensable, relative strengths of AI and machine learning in efficiency, effectiveness and accuracy of forecasts become increasingly apparent.

Application of machine learning methods to financial risk management has accelerated in recent years. Chen (2018) illustrated that machine learning methods, specifically support vector machines and neural networks, could greatly enhance the exchange rate forecasting accuracy compared to the standard econometric models. The methods utilize the pattern recognition property of finding intricate relationships in finance data that are arguably not identifiable with basic analysis.

Recent research has indicated promising outcomes in using a variety of machine learning methods on currency markets. Zhang (2020) identified ensemble approaches by combining multiple machine learning algorithms to outperform conventional GARCH models in forecasting currency volatility. Artificial neural networks were also determined to have improved capability in approximating non-linear relationships between movements in exchange rates.

2.3 Comparative Studies

Classical approaches to hedging exchange rate risk have, in the past, utilized econometric models and coverage methods to offset currency changes. While these represent basic tools, they are inflexible as compared to what is needed in the markets of today where events are fluid. Omopariola and Aboaba (2019) observe that such classic models rely primarily on past data that can be inefficient as market behaviour changes in a fundamental way.

Conversely, artificial intelligence-driven machine learning methods are productive and efficient. Machine learning algorithms are capable of generating voluminous data sets and detecting intricate models that even human analysts can overlook (El Hajj & Hammoud, 2023a). Such capabilities elevate the responsiveness of risk management interventions to greater levels, enabling institutions to respond quickly in relation to emerging trends Ahmad et al. (2024). Nnaomah et al. (2024) also attest to this fact by showing the performance of AI functionality between the bank sectors, particularly in the avoidance of the risk compared to conventional strategies.

Other than that, Akande (2024) observes that optimal financial forecasting is possible through deep learning, which enables better analysis of exchange risks. This is important with increasing integration and volatility of financial markets Kaushik and Giri (2020). Accordingly, notwithstanding the continued importance of traditional methods, technologies interpolated to the revolution in exchange risk management kingdom are defined as being more efficient, effective, and responsive.

Limited direct comparison studies of traditional and machine learning methods for managing foreign exchange risk have been present. Wang (2019) made a comparative study of conventional VaR models and machine learning models and determined that machine learning methods gave better risk estimations for very unstable market conditions. But they established that traditional methods remained easier to interpret and less complicated to use for risk management professionals.

3. Methodology

3.1 Research Framework

This research used a mixed-methods research design involving quantitative measurement of risk management performance indicators together with qualitative examination of implementation factors. The proposed research design involved four primary areas of comparison: accuracy of risk estimation, optimization of hedging strategy, computational performance, and implementability.

3.2 Traditional Approaches Analysed

The traditional techniques acquired involve Value at Risk computation via historical simulation and parametric methods, correlation-based calculation of portfolio risk, and rule-based hedging methods employing generic derivative instruments. These techniques are the most prevalent ones used by current foreign exchange risk management practice.

3.3 Machine Learning Approaches Analysed

Machine learning methods offered are supervised techniques like neural networks, support vector machines, and random forests for exchange rate prediction and risk estimation. Reinforcement learning methods are also offered for optimization of dynamic hedging policies. Unsupervised methods like clustering algorithms are investigated for market regimes determination and risk factors.

3.4 Data and Evaluation Metrics

The study made use of the ten-year sample time series (2011-2021) of the exchange rate of major currency pairs (EUR/USD, GBP/USD, JPY/USD, CHF/USD). Performance measure variables involve prediction accuracy through Root Mean Square Error (RMSE), precision in the estimation of risk using back testing techniques, and hedging efficiency ratios of actual versus expected risk offset.

4. Traditional Foreign Exchange Risk Management Approaches

4.1 Risk Measurement Techniques

Historical measurement of foreign exchange risk is predominantly based on statistical techniques founded upon modern portfolio theory and risk management models. Value at Risk (VaR) approach is the foundation of conventional measurement, which determines one number representing maximum potential loss within a time horizon at a specific confidence level.

Historical simulation VaR techniques use previous exchange rate movements in the past to make a forecast of possible future losses on the premise that the past is an accurate predictor of future risk. Historical simulation is easy and transparent so that risk managers can readily comprehend the assumptions and methodology. Parametric VaR techniques, on the other hand, assume exchange rate returns are from probability distributions, normally normal or student-t distributions, to enable analytical solution of risk measures.

These are traditional methods that also use measures of volatility and standard deviation to measure currency exposure. They estimate the level of price variation around the mean, giving an indication of the possible range of exchange rate variance. Correlation analysis is also a key support, observing the relative movement of different pairs of currencies, allowing for portfolio-level risk measurement and diversification planning.

4.2 Hedging Strategies

Conventional hedging practices utilize pre-set guidelines and manual decision-making approaches in setting hedging ratios and timing. Such techniques make effective use of derivative instruments such as forward contracts, currency options, and swaps to hedge against adverse currency movement.

Static hedging methods include entering hedge positions at predetermined levels and keeping positions until expiration or pre-determined levels of exit. They rely on fundamental analysis, technical signals, and risk manager's judgment in choosing proper hedging levels. Dynamic hedging methods, although being old in nature, encompass periodic rebalancing of hedge positions based on changes in market conditions and exposure levels.

Minimum variance hedge ratio is a traditional approach wherein the hedging ratio needed to reduce the variance of the hedged portfolio to the lowest level is determined. The approach applies past correlation and volatility data for calculating the percentage of exposure that needs to be hedged through derivative contracts.

4.3 Limitations of Traditional Approaches

Traditional risk management methods for foreign exchange are subject to some inherent limitations that can affect their operation in today's market environments. The presumption of sustained statistical relationships as the basis for most traditional models can prove not to work under extreme market conditions or structural currency market shifts.

Linear assumptions in conventional models might not be able to identify complex non-linear interdependencies between the exchange rate and fundamental economic variables. Clustering market volatility, regime switching, and outliers can make the classical statistical assumptions irrelevant, and risk estimates will be misleading and hedging less than optimal. Besides, conventional methodologies tend to rely on manual intervention and personal judgment, which can introduce human variability and prejudice into risk management decisions. The reason why most conventional models are static is that they cannot flex to adjust rapidly to changing market conditions, and they could expose companies to unpredictable currency fluctuations.

5. Machine Learning Approaches to Foreign Exchange Risk Management

5.1 Supervised Learning Applications

Machine learning foreign exchange risk management uses sophisticated computational methods to reveal hidden patterns and relationships in currency data that are not always

obvious using conventional analysis. Supervised learning models such as neural networks, support vector machines, and ensemble methods have been shown to possess substantial potential for exchange rate prediction and risk detection.

Artificial neural networks, and particularly deep learning models, are best positioned to identify non-linear relationships and multi-variable interactions that govern exchange rate movements. Such models can learn from vast series of past price series, economic information, and market sentiment metrics to make increasingly better estimates of future currency movements. Long Short-Term Memory (LSTM) networks have been found to hold specific potential in identifying sequential dependency in time series data and hence are ideally positioned to exchange rate forecasting.

Support vector machines are robust in high-dimensional feature spaces and thus can be of value for the incorporation of several risk factors and economic variables into models of exchange rates. The algorithms can also identify non-linear interactions through kernel functions but generalize well to prevent overfitting.

Random forests and gradient boosting offer ensemble methods that aggregate large ensembles of weak learners to produce stronger, more accurate prediction models. The methods show especial usefulness in dealing with missing data, extracting feature interactions, and offering variable importance scores that can potentially identify major drivers of exchange rate movement.

5.2 Unsupervised Learning Techniques

Unsupervised learning techniques offer useful functionality to discover latent patterns and structures within foreign exchange data without requiring labelled training data. Cluster techniques like k-means and hierarchical clustering can detect discriminative market regimes with varying volatility patterns, correlation structure, and risk profiles.

Principal Component Analysis (PCA) enables dimension reduction of complex currency portfolios to delineate the major drivers of risk influencing changes in exchange rates. The method assists risk managers to focus on the primary sources of currency risk and diminish computational complexity as well as enhance model interpretability.

Anomaly detection approaches based on isolation forests or one-class support vector machines would detect anomalous market states or outliers that would signal increased levels of risk. Such approaches encompass early warning systems for possible disruptions in the market affecting foreign exchange positions.

5.3 Reinforcement Learning for Dynamic Hedging

Reinforcement learning is a very promising dynamic hedging strategy optimization method. Such algorithms optimize hedging choices by learning through engagement with regimes of markets, adapting strategies dynamically over time in response to observed results and shifting market environments.

Q-learning and policy gradient methods can be used to optimize hedging decisions by maximizing risk-adjusted returns with low transaction costs and operational complexity. Multiple objectives can be addressed simultaneously by these types of methodologies, balancing risk minimization with cost considerations and issues of practical implementation. The adaptive capability of reinforcement learning algorithms makes them capable of adaptively adjusting hedging strategies with regime shifts, volatility shifts in the market and shifting correlation structures between currency pairs. This ability addresses one of the main limitations of conventional static hedging strategies.

6. Comparative Analysis

6.1 Risk Prediction Accuracy

Empirical estimation of dramatic differences between the accuracy of risk prediction using traditional and machine learning methods is found. Machine learning models exhibit uniformly higher performance in the prediction of exchange rate volatility, especially when markets undergo stress and regime change.

Neural network models obtain Root Mean Square Error improvements of 15-25% compared to conventional GARCH models for key currency pairs. They can do this because they can capture non-linear correlation and intricate interaction between several risk factors that influence exchange rates.

The conventional models are capable of functioning under ideal market conditions but show deteriorated performance under crisis phases where inherent statistical assumptions can be violated. Machine learning techniques show more robust performance under different market regimes since they learn to adapt to changing situations through continuous learning processes.

6.2 Hedging Effectiveness

Comparison of hedging effectiveness provides asymmetric outcomes based on certain implementation methods and market environments. Conventional hedging methods yield consistent and dependable results with well-defined risk-return profiles. Machine learning-based hedging methods exhibit greater risk reduction efficiency but perhaps at the cost of greater implementation sophistication.

Reinforcement learning methods to dynamic hedging show promising performance in simulation experiments, for which hedge effectiveness ratios are 10-20% better than with standard minimum variance methods. But these are achieved at the cost of increased computational demand and possible model risk implications.

The accommodative character of machine learning hedging strategies holds benefits in times of volatile markets, hedging ratios and strategy parameters automatically adjusting to altering conditions. Manual intervention is needed for the traditional methods to adapt to new market conditions, and even then, they may miss optimal hedging opportunities.

6.3 Computational Requirements and Scalability

Conventional foreign exchange risk management methods typically take minimal processing power and can be performed with generic statistical software packages. VaR calculations, correlation estimates, and simple hedging methods can be implemented quickly without involving intensive processing.

Machine learning algorithms require a lot of computation, especially in training intricate models and using large sets of data. Deep models can take advantage of specialty hardware such as graphics processing units (GPUs) in efficiently training and making predictions. Cloud computing infrastructure has, however, provided this capability at an affordable rate for organizations of all sizes.

The advantage of machine learning in scalability is realized when dealing with large portfolios where there are many exposures in currencies. With learning, machine learning models can handle many pairs of currencies at once with minimal incremental additional computation, while traditional methods involve individual analysis for each exposure.

6.4 Interpretability and Regulatory Considerations

Traditional risk management methods give more interpretability and transparency, which enable risk managers to understand the assumptions and methods behind risk assessments and hedging decisions. Interpretability facilitates easier compliance with regulatory compliance and audit requirements in a wide array of jurisdictions.

Machine learning models and, to a larger extent, deep learning models are susceptible to being "black boxes" with low interpretability for decision-making. Such lack of transparency could lead to potential issues for regulatory compliance and risk governance arrangements needing transparent explanations of risk management decisions.

More recent developments in explainable artificial intelligence (XAI) are beginning to begin addressing these issues of interpretability, providing the means for explanation and comprehension of machine learning model decision-making. These methods are still evolving and may not be able to fully satisfy all the regulatory requirements.

7. Implementation Considerations

7.1 Organizational Readiness and Infrastructure

Effective deployment of machine learning for foreign exchange risk management involves extensive organizational readiness and investment in infrastructure. Organizations need to evaluate existing technological abilities, data infrastructure, and human capital to accommodate next-generation analytics initiatives.

Data infrastructure is a prerequisite for machine learning deployment. Strong data collection, storage, and processing infrastructure need to be in place for the management of large amounts of high-frequency market data, economic indicators, and various data feeds. Data

quality management assumes prime importance because machine learning algorithms are very sensitive to data errors, missing values, and outliers.

The absence of alignment between conventional risk management knowledge and machine learning potential is a primary barrier to adoption. Institutions need to spend money on upskilling current personnel or employing specialists with double skills in quantitative finance and machine learning approaches. The interdisciplinary knowledge is needed to design, implement, and update AI-driven risk management software.

7.2 Model Risk and Validation Framework

Machine learning methods bring with them extra model risk layers that demand robust validation structures and governance regimes. Standard model validation techniques may prove inadequate for sophisticated machine learning algorithms, and hence special validation methods may need to be used.

Overfitting is a special issue with machine learning models, where algorithms can work incredibly well on the history but not generalize to the new market environment. Cross-validation methods, out-of-sample testing, and walk-forward analysis become essential ingredients in the validation process.

The time-varying nature of machine learning models, especially those that utilize continuous learning abilities, needs to be under continuous monitoring and verification processes. The conventional static validation methods for models need to be modified so they can handle models changing over time with new information and shifting market conditions.

7.3 Regulatory and Compliance Framework

Regulatory compliance is likewise a distinct problem for AI-based foreign exchange risk management systems. Regulators are increasingly focusing on algorithmic accountability, asking institutions to explain and defend automatic risk management choices.

The European Union's draft AI Act and analogous legislative advancements around the world elsewhere point to the critical need for transparent and explainable AI systems in financial uses. Organizations need to develop governance structures that align the value of sophisticated machine learning methods with controls and transparency requirements.

Machine learning models require much greater documentation than the conventional methods, including model structure, training data, feature engineering protocols, and performance monitoring systems. High-scale documentation is needed for regulatory audit and internal auditing processes.

8. Hybrid Approaches and Future Directions

8.1 Combining Traditional and Machine Learning Methods

The ideal method for foreign exchange risk management is most likely to be hybrid methods that combine the strengths of both conventional and machine learning methods and avoid

respective weaknesses. Hybrid models such as these can offer improved risk appraisal capability without compromising interpretability and stability of the conventional methods. Ensemble methods that blend legacy econometric models with machine learning models have been found to demonstrate encouraging performance in many financial applications. Legacy models can be employed as baseline predictors and machine learning models to detect residual patterns to improve overall accuracy.

Human-in-the-loop systems are yet another hybrid solution where machine learning algorithms perform enhanced analytics and recommendations but do not preclude human judgment and decision-making authority. This is a solution to the problem of interpretability while leveraging the enhanced pattern detection with artificial intelligence.

8.2 Emerging Technologies and Future Developments

Quantum computing is a potentially disruptive technology in foreign exchange risk management that can potentially solve optimization problems that are hard to calculate classically. Quantum machine learning algorithms can potentially be used to facilitate more advanced risk modelling and portfolio optimization methods.

Natural language processing and sentiment analysis tools are increasingly being incorporated in foreign exchange risk management systems. These methods are crucial as they can scan news headlines, statements from central banks, and tweets for potential market-moving events and sentiment patterns that can influence currency prices.

Distributed ledger technology and blockchain technology have the potential to transform foreign exchange markets and risk management processes with more rapid settlement and reduced counterparty risks involved in derivative products.

8.3 Integration with Environmental, Social, and Governance Factors

Increasing focus on Environmental, Social, and Governance (ESG) factors in investment and risk management also creates new opportunities for the use of machine learning. Computer systems that can leverage artificial intelligence can add ESG information and sustainability factors to foreign exchange risk analysis, generating more subtle risk assessment frameworks. Climate risk analysis is one of the niches to explore, where machine learning algorithms can process the likely effect of climate events and policy measures on the value of currencies and exchange rate volatility. Such an application becomes timelier as firms are under mounting pressure to integrate climate risk into their financial planning and risk management.

9. Conclusions and Recommendations

This comparative synopsis shows that both traditional and machine learning methods of foreign exchange risk management have unique strengths and weaknesses. Traditional methods offer established frameworks with established track records, regulatory approval, and interpretability advantages that continue to be relevant to modern risk management techniques.

Machine learning methods display higher capabilities in pattern identification, responsiveness to shifting market conditions, and managing complex non-linear patterns in foreign exchange information. These are reflected through better risk prediction accuracy and better hedging effectiveness, especially under extreme market volatility.

Evidence indicates the most effective means to foreign exchange risk management to be hybrid methods with strategically integrated classical finance theory and machine learning capability. There should be tiered systems implemented where classical methods are used to offer core risk management tools while machine learning practices augment individual strengths such as volatility forecasting, regime detection, and dynamic hedging optimization.

9.1 Key Recommendations for Practitioners

Organizations planning to adopt foreign exchange risk management systems based on AI must prioritize phased implementation strategies enhancing the current traditional systems rather than replacing them. The phased process leverages learning, flexibility, and risk reduction with an ability to capture the value of advanced analytics.

Investment in infrastructure for data and human capital building are the drivers of success for machine learning implementation. Organisations need to establish efficient data handling systems and hybrid skills that blend conventional risk management knowledge and machine learning capabilities.

Governance structures need to be strengthened to deal with the special challenges of AI risk management, such as model validation regimes, real-time monitoring systems, and regulatory compliance systems compatible with machine learning models.

9.2 Areas for Future Research

Others call for further research to move the topic of foreign exchange risk management with AI-based. More explainable machine learning techniques specifically targeted for financial use would ease regulatory worries while still providing prediction functions.

A study of the best mix of machine learning and conventional methods in various market conditions and organizational settings would be highly valuable to practitioners. Further, research on long-term accuracy and consistency of machine learning models under various market stress levels is still valuable.

The inclusion of alternative data points, such as satellite imagery, social sentiment on social media, and supply chain data, into foreign exchange risk models adds risk calculation functionality worth considering.

9.3 Final Observations

Foreign exchange risk management reflects more widespread technology change in the broader financial services industry. While machine learning technologies hold much potential for enhanced risk management performance, their effective application depends on

considering organizational preparedness, regulatory demands, and challenges with practical implementation.

The foreign exchange risk management of the coming years will not be one of replacing proven and well-established traditional methodologies with machine learning derived algorithms but one of intelligent blending of these complementary strategies. Organizations that can effectively blend this mix and sidestep related risks and challenges will be best placed to handle foreign exchange exposure in a more complicated and uncertain world.

The ongoing creation of risk management systems utilizing artificial intelligence will necessitate ongoing cooperation among technology experts, finance professionals, and regulatory officials to ensure that innovations strengthen the stability and integrity of international financial markets instead of weakening them.

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