"EXPLORING THE EFFICIENCY AND ACCURACY OF AI-POWERED PREDICTIVE ANALYTICS: A SIX COUNTRY CASE STUDY OF THE LOGISTIC PERFORMANCE INDEX"

Research paper

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Abstract

This research assesses the logistics performance index (LPI) scores for six different countries: Nigeria, Malaysia, Sweden, the United States, Bolivia, and Papua New Guinea. The LPI serves as an indicator of a country's logistics efficiency, covering aspects such as infrastructure and timeliness, and is a key metric for sustainable logistics practices. Using traditional machine learning models, we compare our predicted scores with the actual results for 2023. Initial findings suggest a trend of conservative predictions, with several countries surpassing their forecasted performance, indicating progress in sustainable logistics. Interestingly, Bolivia and Papua New Guinea stand out, demonstrating unexpected progress and diverse approaches to development. While recognizing the limitations of model biases and sudden geopolitical changes, the study highlights the importance of predictive analytics in understanding global logistics and sustainability trends, providing a solid foundation for future detailed studies into balancing economic development and environmental protection.

Keywords: Artificial Intelligence (AI), Machine Learning (ML), Logistics, Logistics Performance Index (LPI), Supply Chain Management (SCM), Sustainability.

1 Introduction

In our interconnected world, streamlined global logistics are vital for a nation's development and competitive edge in international trade. Proficiently managed logistics services to expedite product movement and enhance safety protocols, ultimately reducing the costs associated with international trade. The pursuit of logistics excellence provides companies with a distinct competitive advantage, enabling swift and cost-effective product delivery while ensuring customer satisfaction. Therefore, improving logistics performance through the development of transport infrastructure, logistics services, port, and logistics centre efficiency, as well as the continuous enhancement of information systems, is crucial for enhancing a country's trade performance (Arvis et al., 2007). Shepherd (2011) acknowledged the inherent importance of the logistics sector, and the logistics performance index (LPI) stands as a robust and essential instrument for appraising the efficiency and effectiveness of logistics operations.

According to Bugarčić et al. (2020), the LPI is one of the quantitative measures for assessing logistics support and its growth. It meticulously evaluates and ranks the performance of logistics and supply chain operations, offering valuable insights into a country's logistics landscape. The LPI combines quantitative data, surveys, and expert assessments to provide a comprehensive assessment, allowing for a holistic view of logistics performance. Each component receives a score, amalgamated to form an overarching LPI score, which in turn serves as a benchmark for international comparison.

A positive effect on global trade facilitation can be achieved by improving logistics performance (Shepherd, 2017), and the LPI is widely embraced by governments, businesses, and policymakers, serving as a compass to identify areas where logistics and supply chain operations can be fine-tuned. It empowers nations and enterprises to make data-driven decisions, refining trade facilitation measures, reducing costs, and elevating global competitiveness. Furthermore, the LPI champions transparency and

accountability in logistics procedures, thereby contributing significantly to the seamless flow of international trade and the advancement of economic growth.

Predictive analytics, with its advanced mathematical and statistical tools, assumes a pivotal role in modern decision support systems. Businesses acknowledge that mastering logistics is essential for sustainable growth. Artificial intelligence (AI) is revolutionizing logistics, enabling greater efficiency and optimization. AI's transformative capacity surpasses that of traditional digital applications, making it crucial for companies to embrace AI in order to remain innovative and successful as it continues to evolve (Candelon et al., 2020).

1.1 Role of logistics in global trade, economic growth, and sustainability

Logistics stands out as one of the essential elements for the competitiveness of an economy (Arvis et al., 2007), serving as a fundamental catalyst for global trade, economic development, and sustainability. Its proficiency in facilitating the movement of goods and services, cost` mitigation and commitment to sustainable practices is pivotal in shaping a more interconnected and sustainable global economy. Operating as the linchpin of global trade and economic progress, logistics achieves this by enhancing supply chain efficiency, curbing expenses, creating employment opportunities, and adopting environmentally responsible approaches. As the conduit connecting global producers and consumers, optimising expenditure, and championing sustainability, logistics plays an irreplaceable role in moulding a more interconnected and sustainable global economic landscape.

1.2 Impact of logistics on economies, businesses, and the environment

Logistics plays a vital role in global trade, economic growth, and sustainability by enabling efficient trade, cost reduction, competitiveness, and environmental responsibility. Aytekin et al. (2023) underscore the crucial link between logistics and a country's capacity to increase its global market presence, underscoring the significance of a strong logistics sector and infrastructure. Understanding and predicting logistics performance are critical for economic growth, business competitiveness, and environmental sustainability. This necessitates a holistic approach that combines business expertise, technology, and environmental consciousness. Comprehensive logistics management is crucial, with relevant studies providing valuable insights.

Enhancing logistics performance, including the expansion of transport infrastructure, optimization of logistics services, increased efficiency of ports and logistics centres, and the ongoing enhancement of information systems, is pivotal for boosting a country's trade performance (Arvis et al., 2007). Leading global trade and logistics nations set a gold standard through investments and infrastructure advancements. These initiatives not only inspire emulation but also elevate global connectivity and efficiency standards, promoting a more interconnected and prosperous world. Governments and businesses must prioritize investments in logistics infrastructure and practices to harness the benefits of a highly interconnected global economy while ensuring sustainability for future generations.

1.3 Significance of understanding and predicting logistics performance

The LPI, a biannual assessment of nations' logistics performance, is a crucial tool in trade facilitation efforts. Wong and Tang (2018) emphasise its significance in offering a macroeconomic perspective for policymakers to enhance global supply chain capabilities and business performance by focusing on factors like clearance efficiency, trade quality, and transportation infrastructure. Understanding and predicting logistics performance is vital due to its widespread impact on economies, businesses, and the environment.

Logistics plays a pivotal role in global trade, economic growth, and sustainability. It influences carbon emissions and resource conservation, aligning with sustainability goals and environmental regulations (Seuring and Müller, 2008). Efficient logistics yield economic benefits, improving cost efficiency, trade, and GDP growth. They also benefit businesses by optimizing distribution networks and ensuring

customer satisfaction. Nonetheless, logistics also affect the environment, contributing to emissions and resource waste, necessitating eco-friendly practices and regulatory compliance.

1.4 Research gap

Addressing gaps in logistics performance literature and practical applications can lead to more efficient and sustainable operations. These gaps include 1. underutilization of AI, 2. lack of comprehensive LPI prediction studies, 3. insufficient research on logistics sustainability, 4. emerging technologies integration, 5. supply chain resilience, 6. SME (small and medium-sized enterprises) focused research, and 7. cross-disciplinary collaboration. Filling these gaps is crucial for optimizing logistics, benefiting businesses, economies, and the environment while enhancing supply chain resilience and innovation in a rapidly changing world.

1.5 Research objective

This research aims to leverage explorative predictive analytics for forecasting LPI scores in selected countries and to rigorously evaluate the accuracy and effectiveness of these predictions by comparing them with actual LPI scores. By doing so, this study seeks to provide valuable insights into the predictive potential of modelling techniques in the realm of logistics performance assessments.

2 Literature review

The pursuit of enhancing logistics performance has emerged as a crucial development policy objective and the LPI, introduced by the World Bank in 2007 (Arvis et al., 2007), serves as a valuable instrument for monitoring a nation's logistic performance. This dynamic tool has evolved significantly since its inception to evaluate various aspects of logistics performance on a global scale. The six components of LPI offer a comprehensive view of a country's logistics efficiency, making it invaluable for governments, businesses, and researchers in the context of international trade and supply chain management. This is particularly important as improvements in the supply chain significantly enhance competitiveness by lowering transaction costs (Arvis et al., 2007).

2.1 History of LPI

Trade and logistics are intricately connected to a nation's economic competitiveness, heavily influenced by policies. The LPI emerged in 2007 as a vital tool, introduced by the World Bank to measure and enhance global logistics performance. Engaging in collaborative efforts with international organizations, academic institutions, and stakeholders within the logistics industry, the LPI has undergone a series of revisions and refinements aimed at enhancing its accuracy and relevance (Ojala and Celebi 2015).

The logistics sector plays a crucial role in trade facilitation, transportation cost reduction, and economic growth (Bugarčić et al., 2020). Efficient logistics systems directly influence industry profitability through elements such as inventory reduction, rapid responsiveness to demand fluctuations, shorter lead times, and the minimization of transportation costs. Thus, logistics systems are not just seen as production factors but also as critical determinants in facility location decisions.

According to Ojala and Celebi (2015), the World Bank's LPI is the most comprehensive tool for international comparisons of trade and transport facilitation friendliness among countries. Understanding and dissecting trade and logistics performance components can help countries enhance freight transport efficiency and identify areas where international cooperation can overcome barriers.

2.2 Components of LPI

Ojala and Celebi (2015) emphasize that understanding and dissecting. the components of logistics performance as well as trade can facilitate countries to improve freight transport efficiency and identify areas where international cooperation can be beneficial. This process involves identifying weaknesses

and opportunities within logistics systems to enhance competitiveness in global trade and collaborate with other nations to address shared challenges.

The LPI is often compiled and published by international organizations like the World Bank or other industry-related bodies, and it consists of six key components, each offering insights into different aspects of logistics performance. This is illustrated in figure 1.

Figure 1. Various facets of LPI

1. **Customs clearance process**: This component assesses the efficiency of customs and border clearance processes, encompassing documentation, inspections, and associated fees. It also measures the efficiency and simplicity of customs agencies. To achieve efficient customs clearance, it is crucial for this process to be as streamlined as possible, minimizing bureaucratic procedures (Arvis et al., 2016).

2. **Infrastructure quality**: This component evaluates the quality and adequacy of transport infrastructure, including roads, ports, and railroads. According to Arvis et al. (2016), the quality of transport infrastructure is essential for logistics and international trade, encompassing roads, railways, ports, and airports. Enhanced transport infrastructure contributes to a smoother flow of physical goods traffic, facilitating faster and safer transportation.

3. **Ease of arranging shipments**: This aspect assesses the ease with which shipments can be scheduled and coordinated, considering factors such as booking, scheduling, and tracking. As stated by Arvis et al. (2016), it involves the ease of organizing international shipments and ensuring their timely delivery at competitive prices.

4. **Competence and quality of logistics services**: This component gauges the quality of logistics services delivered by various firms, encompassing transport operators, customs brokers, and freight forwarders. As indicated by Arvis et al. (2016), it pertains to the quality and competence of logistics services and operators, including those involved in trucking, forwarding, and customs brokerage.

5. **Tracking and tracing**: This component evaluates the presence and utilization of tracking and tracing systems for monitoring the movement of goods. As noted by Arvis et al. (2016), it pertains to the capability to efficiently track and locate shipments.

6. **Timeliness of deliveries**: This aspect assesses the punctuality and dependability of delivery services, considering factors such as delivery times and on-time performance. As mentioned by

Arvis et al. (2016), it involves the timely delivery of shipments within the planned or expected deadlines.

These components collectively provide a comprehensive view of a country's logistics performance, helping policymakers and businesses identify areas for improvement and collaboration.

2.3 Significance in global trade and logistics

The LPI holds significant importance in several ways which include: -

1. **Benchmarking**: It allows countries to benchmark their logistics performance against global standards, identifying areas for improvement.
2. **Trade facilitation**: A high LPI score signifies efficient logistics systems, which can attract foreign investment and promote international trade.
3. **Policy development**: Governments and policymakers use LPI data to develop policies and infrastructure investments aimed at enhancing logistics efficiency.
4. **Business decision-making**: The LPI assists businesses in selecting strategic locations for their operations and optimizing SCM.
5. **Research and analysis**: The LPI is derived from a global survey, and according to Arvis et al. (2016), researchers and analysts utilize LPI data to examine trends in global logistics performance and their effects on economies.

2.4 Previous predictive models

According to Steyerberg et al. (2001), the performance of a predictive model is overestimated when simply determined by the sample of subjects that was used to construct the model. Predictive models in logistics, ranging from time series analysis to machine learning (ML) algorithms, have a rich history of improving operational efficiency and decision-making. These models use historical data and patterns to forecast demand, optimize routes, and minimize costs.

As noted by Bharadiya, J.P. (2022), the demand for real-time analytics is on the rise as businesses seek greater agility and the ability to make proactive decisions. Traditional methods such as linear regression and mathematical optimization have evolved into advanced ML and simulation techniques. Specialized software and tools cater to logistics predictive analytics, including demand forecasting and weather integration. These models empower organizations to make data-driven decisions, reduce expenses, and enhance supply chain efficiency. As data availability and technology advance, predictive models will likely play an increasingly crucial role in responsive SCM.

2.5 Machine learning in logistics

The rapid advancement of automation is driving strategists to reconfigure their business models, as illustrated by Sony et al. (2019). Simultaneously, ML is evolving and progressively integrating into logistics operations. As businesses generate and collect more data, the potential for ML to enhance efficiency, reduce costs, and improve sustainability in the logistics sector remains substantial. AI holds transformative potential for bolstering manufacturing and supply chain resilience while achieving cost efficiencies (Candelon et al., 2020).

AI has the potential to facilitate both predictive and prescriptive analytics, as highlighted by Chaudhuri et al. (2021). Furthermore, AI-powered predictive analytics is currently revolutionizing logistics management, delivering unprecedented levels of efficiency and precision. Key applications encompass demand forecasting, route optimization, quality control, demand-driven production, inventory management, warehouse operations, supply chain visibility, supplier selection, reverse logistics, and sustainability initiatives. Embracing AI in logistics facilitates data-driven decision-making, automation, and a competitive edge in today's dynamic global market. AI's future promises end-to-end visibility,

autonomous decision-making, and sustainable practices, rendering it indispensable for business competitiveness and resilience.

Predictive analytics leverages AI and machine ML algorithms to examine historical data and formulate predictions or forecasts concerning future outcomes (Sony et al., 2019). The integration of AI into logistics management presents significant advantages, including cost reduction, enhanced efficiency, improved customer service, and overall performance optimization. However, successful implementation relies on proper data collection, data quality, and organizational alignment. Challenges such as data security, integration complexities, and the demand for skilled personnel to handle AI-driven insights persist. Businesses that effectively adopt AI technologies and address these obstacles can gain a competitive advantage in the fast-changing and intricate global supply chain landscape.

2.6 Importance of accurate LPI prediction

LPI consists of several essential components (Babayigit et al., 2023), and the accurate prediction of LPI is of utmost importance for several compelling reasons. It serves as the bedrock for making well-informed decisions in the realm of economic strategy, providing invaluable assistance to governments and businesses in optimally allocating resources and strategically planning infrastructure development. The LPI exercises a direct and profound influence on global trade competitiveness, offering valuable guidance to entities keen on evaluating and fortifying their logistics prowess.

The prediction of the LPI index guides countries in determining their local priorities (Babayigit et al., 2023), and precision in LPI predictions results in cost-effective logistics operations, streamlined supply chain efficiency, and increased customer satisfaction. It serves as a linchpin for identifying and mitigating risks, thereby fortifying the continuity of business operations. The LPI is a cornerstone for countries seeking to evaluate their trade processes, and accurate predictions simplify and expedite international trade procedures.

In addition, the LPI plays a pivotal role in advancing sustainability initiatives, enabling the effective implementation of environmentally friendly practices. In essence, the power of accurate LPI predictions empowers both organizations and governments to take proactive measures aimed at elevating their logistics and supply chain performance, ultimately contributing to robust economic growth, and bolstering global competitiveness.

2.7 Sustainability in logistics

Sustainability in logistics is a critical area of research and practice, focusing on reducing the environmental impact of supply chain and transportation operations while maintaining or enhancing performance. Here is a review of literature that explores the connection between logistics performance and sustainability, including studies on green supply chains, the environmental impact of inefficient logistics, and the economic benefits of sustainable logistics practices.

Srivastava (2007) on green supply chains and sustainability, highlights the importance of green SCM in reducing environmental impacts. It discusses various strategies, such as green procurement, eco-design, and reverse logistics, and their potential to improve sustainability while maintaining supply chain performance. The study by Sarkis et al., (2011) provides an overview of sustainable SCM literature, emphasizing the integration of environmental and social concerns into logistics practices. It discusses the benefits of adopting sustainability initiatives, including cost reduction and improved brand reputation.

A study conducted by Peters et al. (2011) on the environmental impact of inefficient logistics, quantified the carbon emissions associated with inefficient logistics and long-distance trade. This study underscores the environmental consequences of suboptimal routing and inventory management, as well as the potential for emissions reduction through improved logistics practices. The study conducted by Dente and Tavasszy (2018) evaluates the environmental impact of various urban freight transport modes and logistics strategies. It emphasizes the crucial role of sustainable urban logistics in mitigating air pollution, alleviating congestion, and reducing carbon emissions.

The research conducted by Eccles et al. (2014) on the economic benefits of sustainable logistics practices, investigates the relationship between sustainability practices and financial performance. It suggests that companies that embrace sustainable logistics practices can attain long-term profitability by decreasing operational costs and bolstering customer loyalty. The study conducted by Zhu et al. (2012) delves into the impact of green SCM practices on firm performance. It concludes that companies that incorporate sustainability into their logistics operations can realize both environmental benefits and enhanced financial performance.

Sustainable logistics technologies assess the environmental impact of last-mile delivery options in e-commerce, including traditional delivery methods and alternative approaches such as electric vehicles and cargo bikes (Zubin et al. 2020). It underscores the potential of sustainable logistics technologies to mitigate emissions. A study conducted by Cano et al. (2022), explores how autonomous vehicles can contribute to sustainable logistics. It discusses the potential for enhanced fuel efficiency, decreased congestion, and optimized route planning through autonomous transportation systems.

2.8 AI-Powered predictive analytics

According to Bharadiya, J.P. (2022), AI and BI (Business Intelligence) are two transformative technologies with the potential to fuel substantial business growth and confer a competitive advantage. So, AI-powered predictive analytics is a transformative tool that empowers organizations to make data-driven decisions, optimize operations, lower costs, and extract valuable insights from their data. As AI technologies continue to advance, the applications and benefits of predictive analytics are likely to expand even further across various sectors. It is driven by real-time data analysis, enabling the use of up-to-the-minute information from diverse sources like IoT (Internet of Things) devices. Additionally, it aids in risk mitigation by identifying supply chain risks, allowing proactive mitigation strategies based on historical data and external factors to ensure business continuity.

The fast pace of AI and automation is propelling strategists to reshape the business models Soni, et al., (2019). AI algorithms have the capacity to automate data cleansing, data integration, and data transformation processes, thereby reducing manual effort and enhancing data quality. In the context of logistics efficiency, the effectiveness of AI-powered predictive analytics depends on various factors, including data quality, model complexity, and continuous optimization. It enhances demand forecasting accuracy, reducing inventory costs and stockouts. AI optimizes inventory levels by predicting demand changes and identifying slow-moving items. It also aids supply network optimization by evaluating routes, lead times, and supplier performance, facilitating informed decisions to boost supply chain efficiency.

AI empowers predictive and prescriptive analytics within BI systems, surpassing traditional descriptive analytics (Bharadiya, J.P. 2022). The accuracy of AI-powered predictive analytics has evolved into a pivotal factor influencing its widespread adoption and successful implementation across diverse industries and domains. The ongoing development of AI is marked by advancements in ML algorithms, data collection, and processing capabilities, significantly enhancing the precision and reliability of predictive analytics models.

3 Methodology

The dataset for this research was sourced from the World Bank, a comprehensive repository of LPI scores spanning numerous countries worldwide. This dataset gives a detailed look at the various aspects of how well logistics are performing, captured across different years: 2007, 2010, 2012, 2014, 2016, 2018, and 2023. Each year's data was initially segmented into individual tabs within an Excel file. The initial stage involved an exploratory data analysis to understand the dataset's structure and content. This exploration provided insights into several core metrics that define logistics performance, such as customs, infrastructure, international shipments, quality logistics services, tracking and tracing, and timeliness. Each of these metrics offers a unique perspective on the logistics capabilities of a country, from the efficiency of customs clearances to the punctuality of shipments.

Subsequently, a data cleaning procedure was initiated to ensure uniformity and coherence across all years. Each year's data, segmented within its respective tab, was consolidated into a single time-series dataset. The AI-powered advanced data analysis tool from Open AI, also formerly known as the code interpreter, was employed for the computational components of this research. This advanced model provided the project with the necessary computational strength required for training models, and predictive analytics as well as partially for data manipulation. For the predictive modelling phase, the dataset was filtered to extract historical data from the years 2007 to 2018. This subset was used to train three ML models linear regression (LR), decision tree (DT), and random forest (RF) to predict the LPI scores for 2023. The models were applied to six randomly chosen countries, one from each continent, in the dataset: Nigeria, Malaysia, Sweden, United States, Bolivia, and Papua New Guinea. The predictions were then rounded to two decimal places for uniformity and clarity.

To ensure that the model's predictions were accurate, the predicted values were compared against the actual LPI scores for 2023. This validation process was crucial to ascertain the reliability and efficacy of the trained models. The mean absolute error (MAE) was chosen as the primary metric to assess the accuracy of these models in predicting the LPI scores for 2023. Furthermore, we also ran the process twice, to ensure that we obtained comparable results. Fully identical results are not possible due to that there are random components involved in both the DT as well as RF models. In conclusion, this research not only delved deep into the logistics performance of six distinct countries but also demonstrated the application and power of ML models in predicting future trends based on historical data.

4 Results

The results section highlights the outcomes of the predictive models in relation to the actual scores for the year 2023, spanning various metrics of the Logistics Performance Index. The chapter will highlight comparisons of actual scores with model predictions for each of the specific metrics: Overall LPI scores, customs, infrastructure, international shipments, quality logistics services, tracking and tracing, and timeliness.

4.1 Overall LPI scores

Table 1 showcases the overall LPI scores for 2023, comparing the actual values against the predictions from the three models: LR, DT, and RF. Upon analysis, Nigeria, Malaysia, and Papua New Guinea exhibit a trend where all model predictions consistently fall below the actual values. In contrast, Sweden and the United States have model predictions that consistently overshoot the actual values. Bolivia presents a unique case with mixed predictions, where some models predict higher while others predict lower than the actuals. This analysis sheds light on the diverse predictive behaviour of the models across different countries.

Country	**Actuals**	**LR**	**DT**	**RF**
Bolivia	2.40	2.42	2.36	2.35
Malaysia	3.60	3.44	3.22	3.31
Nigeria	2.60	2.56	2.53	2.52
Papua New Guinea	2.70	2.38	2.17	2.28
Sweden	4.00	4.03	4.05	4.06
United States	3.80	3.90	3.89	3.92

Table 1. Actual vs. predicted overall LPI scores for the year 2023.

4.2 Customs scores

Table 2 presents the custom scores for 2023, showing the actual values against the predictions from the three models. From the data, Nigeria and Papua New Guinea manifest a trend where all model predictions are consistently lower than the actual values. On the other hand, the United States and Bolivia stand out with model predictions that consistently surpass the actual values. Malaysia and

Sweden offer varied outcomes with mixed predictions, where certain models suggest higher scores and others lower, compared to the actuals.

Country	Actuals	LR	DT	RF
Bolivia	2.10	2.34	2.32	2.24
Malaysia	3.30	3.31	2.90	3.01
Nigeria	2.40	2.30	1.97	2.10
Papua New Guinea	2.40	2.32	2.32	2.34
Sweden	4.00	3.97	4.05	3.96
United States	3.70	3.80	3.78	3.73

Table 2. Actual vs. predicted customs scores for the year 2023.

4.3 Infrastructure scores

Table 3 presents the Infrastructure Scores for 2023, juxtaposing the actual values against the predictions from the three models: LR, DT, and RF. From the data, Malaysia, Bolivia, and Papua New Guinea display a trend where all model predictions consistently fall short of the actual values. Conversely, Nigeria and the United States demonstrate a pattern where model predictions consistently exceed the actual values. Sweden offers a distinctive outcome with mixed predictions, showcasing variations where certain models suggest higher scores and others lower, compared to the actuals. This examination provides a deeper understanding of the varied predictive performance of the models across different countries.

Country	Actuals	LR	DT	RF
Bolivia	2.40	2.26	2.11	2.19
Malaysia	3.60	3.48	3.42	3.38
Nigeria	2.40	2.48	2.56	2.50
Papua New Guinea	2.40	2.18	2.02	2.08
Sweden	4.20	4.22	4.19	4.22
United States	3.90	4.20	4.11	4.12

Table 3. Actual vs. predicted infrastructure scores for the year 2023.

4.4 International shipments scores

Table 4 details the international shipments scores for 2023, comparing the actual values against the predictions from the three models. Analysis of the data reveals that Malaysia, Bolivia, and Papua New Guinea consistently have model predictions that fall below the actual scores. In contrast, Nigeria, Sweden, and the United States exhibit model predictions that surpass the actual values.

Country	Actuals	LR	DT	RF
Bolivia	2.50	2.44	2.45	2.45
Malaysia	3.70	3.42	3.41	3.42
Nigeria	2.50	2.55	2.62	2.55
Papua New Guinea	2.60	2.39	2.37	2.39
Sweden	3.40	3.77	3.81	3.78
United States	3.40	3.46	3.50	3.48

Table 4. Actual vs. predicted international shipment scores for the year 2023.

4.5 Quality Logistics Services scores

Table 5 presents the quality logistics services scores for 2023, comparing the actual values against the predictions from the three models: LR, DT, and RF. The data reveals that Malaysia, Sweden, Bolivia, and Papua New Guinea consistently have model predictions that are below the actual scores. Conversely, Nigeria stands out with predictions that consistently surpass the actual values. The United States exhibits a unique pattern with mixed model predictions, aligning closely with its actual score.

Country	Actuals	LR	DT	RF
Bolivia	2.40	2.29	2.13	2.22
Malaysia	3.70	3.36	3.35	3.35
Nigeria	2.30	2.50	2.60	2.48
Papua New Guinea	2.70	2.20	2.02	2.11
Sweden	4.20	4.04	4.04	4.04
United States	3.90	3.90	3.89	3.89

Table 5. Actual vs. predicted quality logistics services scores for the year 2023.

4.6 Tracking and tracing scores

Table 6 portrays the tracking and tracing scores for 2023, showing the actual values against the predictions from the three models. The data indicates that Malaysia, the United States, and Papua New Guinea consistently have model predictions that fall below the actual scores. In contrast, Nigeria, Sweden, and Bolivia demonstrate a trend where model predictions consistently exceed the actual values.

Country	Actuals	LR	DT	RF
Bolivia	2.50	2.68	2.71	2.69
Malaysia	3.70	3.61	3.64	3.62
Nigeria	2.70	2.87	2.93	2.91
Papua New Guinea	3.00	2.72	2.69	2.71
Sweden	4.10	4.16	4.29	4.23
United States	4.20	3.99	4.03	4.03

Table 6. Actual vs. predicted tracking and tracing scores for the year 2023.

4.7 Timeliness scores

Table 7 offers a comprehensive view of the differences between the actual 2023 Timeliness scores and the predictions from each of the three models. The analysis reveals that for countries such as Nigeria, Malaysia, Sweden, and Papua New Guinea, the predicted scores consistently fall short of the actual values. In contrast, the United States has predictions that consistently exceed its actual score. Bolivia stands out with mixed model predictions. Overall, the trend of predictions being lower than the actual scores, as observed in previous metrics, holds true for most countries in this table as well.

Country	Actuals	LR	DT	RF
Bolivia	2.40	2.45	2.27	2.35
Malaysia	3.70	3.44	3.28	3.36
Nigeria	3.10	2.63	2.72	2.66
Papua New Guinea	3.30	2.40	2.14	2.28
Sweden	4.20	4.08	3.95	4.01
United States	3.80	4.13	4.09	4.13

Table 7. Actual vs. predicted timeliness scores for the year 2023.

To summarize, this results section delivered a detailed examination of the predictive capabilities of the three ML models across multiple logistics performance indicators, such as overall LPI scores, infrastructure, international shipments, quality logistics services, timeliness, and tracking & tracing. While there were instances where the models' predictions exceeded the actual scores, a consistent trend emerged across most countries and metrics: the models frequently predicted scores that were lower than the actual 2023 values. Notably, there were some exceptions and mixed predictions, underscoring the nuanced behavior of these models across different datasets. These insights are invaluable, highlighting the inherent conservatism of the models and their potential implications when utilized for future forecasting or in different contexts.

5 Discussion

The application of predictive analytics together with LPI provided a detailed overview of the logistics scenario for six diverse countries. The comparison of our predictions with the actual 2023 scores offers multifaceted insights. A preliminary analysis suggests that many countries have made progress in their logistics sectors. This progress, possibly influenced by sustainable practices, is evident in areas like customs, infrastructure, and timeliness. The difference between the predicted values and actual scores might indicate a rapid uptake of sustainable initiatives in recent years.

Efficiency in logistics, especially in areas like timeliness and infrastructure, has direct implications for sustainability. Delays can lead to higher energy use and waste. The prediction errors in timeliness for countries such as Nigeria and the United States could point to their efforts to reduce energy consumption and their carbon footprints. The infrastructure metric showed varied results. For instance, while Malaysia did not meet the predicted standards for 2023, Nigeria exceeded them. This difference indicates diverse directions in sustainable infrastructure development, possibly influenced by external events or internal policy decisions.

Other metrics, like quality of logistics services and tracking and tracing, bring up the efficiency and transparency of operations. Higher scores in these areas suggest a focus on streamlined and transparent logistics operations, which are inherently more sustainable. However, consistent underpredictions in areas like customs and international shipments might suggest a global trend towards more efficient customs processes and improved international shipping operations. Such improvements could be driven by a desire to reduce environmental impacts and enhance international collaborations.

Interestingly, countries like Bolivia and Papua New Guinea, which are not typically in the spotlight for logistics, have shown significant growth. This observation raises the question of whether lesser-known countries are adopting sustainable logistics practices faster than anticipated. It is essential to interpret these findings with caution. While predictive models are powerful, they come with their biases. Relying heavily on historical data may not capture sudden changes, such as policy decisions or geopolitical events, which can dramatically impact logistics.

Furthermore, the study's methodology had limitations. Using a linear trend to simulate past scores may not always reflect the reality of LPI scores. The inherent biases in ML models can also influence the results. To achieve more accurate results, refining the models or data might be necessary, but this could compromise the integrity of the research. For future studies, a more detailed analysis using monthly or quarterly LPI scores could be beneficial. Including more varied data points, like economic indicators or technological adoption rates, could provide a more comprehensive view of global logistics trends.

To summarize, understanding the relationship between LPI scores and sustainability is crucial. As countries strive for economic growth and environmental sustainability, this study emphasizes the value of predictive analytics. By understanding trends and making informed predictions, countries can better plan for a sustainable future in logistics.

6 Conclusion

This research used predictive analytics to evaluate logistics performance in six randomly chosen countries, one from each continent, using the LPI scores from the World Bank. The comparison of predicted and actual 2023 scores highlighted the capabilities and limitations of ML in this context. Initial findings suggest a trend of conservative predictions, with several countries surpassing their forecasted performance, indicating progress in sustainable logistics. The results underscore the balance that countries must strike between economic growth and sustainable logistics practices.
To better prepare for a sustainable future in the field of logistics, it is essential to not only comprehend current trends but also to make well-informed predictions. The study's findings offer a foundation for further research in this important and emerging area of study. Suggestions for the future include adding more countries into the analysis and also utilizing other ML models, in addition to LR, DT and RF.

References

Arvis, J.F., Alina Mustra, M., Panzer, J., Ojala, L. and Naula, T. (2007). *Connecting to compete 2007: Trade logistics in the global economy.* World Bank group.

Aytekin, A., Korucuk, S. and Karamaşa, Ç. (2023). "Ranking countries according to logistics and international trade efficiencies via REF-III." *J. Intell. Manag. Decis*, 2, pp.74-84.

Bharadiya, J.P. (2022). "Driving Business Growth with Artificial Intelligence and Business Intelligence." *International Journal of Computer Science and Technology*, 6(4), pp.28-44.

Candelon, F., Reichert, T., Duranton, S., di Carlo, R.C. and De Bondt, M. (2020). *The rise of the AI-powered company in the post-crisis world*. Boston Consulting Group, p.7.

Cano, J.A., Londoño-Pineda, A. and Rodas, C. (2022). "Sustainable logistics for e-commerce: A literature review and bibliometric analysis." *Sustainability*, 14(19), p.12247.

Chaudhuri, R., Chatterjee, S., Vrontis, D. and Thrassou, A. (2021). "Adoption of robust business analytics for product innovation and organizational performance: the mediating role of organizational data-driven culture." *Annals of Operations Research*, pp.1-35.

Dente, S.M. and Tavasszy, L. (2018). "Policy-oriented emission factors for road freight transport." *Transportation Research Part D: Transport and Environment*, 61, pp.33-41.

Eccles, R.G., Ioannou, I. and Serafeim, G. (2014). "The impact of corporate sustainability on organizational processes and performance." *Management Science*, 60(11), pp.2835-2857.

Navickas, V., Sujeta, L. and Vojtovich, S. (2011). "Logistics systems as a factor of country's competitiveness." *Ekonomika ir vadyba*, (16), pp.231-237.

Ojala, L. and Celebi, D. (2015). The World Bank's Logistics Performance Index (LPI) and drivers of logistics performance. *Proceeding of MAC-EMM,* OECD, pp.3-30.

Sarkis, J., Zhu, Q., and Lai, K.H. (2011). "An organizational theoretic review of green supply chain management literature." *International journal of production economics*, 130(1), pp.1-15.

Seuring, S. and Müller, M. (2008). "From a literature review to a conceptual framework for sustainable supply chain management." *Journal of cleaner production*, 16(15), pp.1699-1710.

Shepherd, B. (2011). *Logistics costs and competitiveness: measurement and trade policy applications.* Transport Research Support Working Paper, World Bank.

Soni, N., Sharma, E.K., Singh, N. and Kapoor, A. (2019). *Impact of artificial intelligence on businesses: from research, innovation, market deployment to future shifts in business models*. arXiv:1905.02092.

Srivastava, S.K. (2007). "Green supply-chain management: a state-of-the-art literature review." *International journal of management reviews*, 9(1), pp.53-80.

Steyerberg, E.W., Harrell Jr, F.E., Borsboom, G.J., Eijkemans, M.J.C., Vergouwe, Y. and Habbema, J.D.F. (2001). "Internal validation of predictive models: efficiency of some procedures for logistic regression analysis." *Journal of clinical epidemiology*, 54(8), pp.774-781.

Wong, W.P. and Tang, C.F. (2018). "The major determinants of logistic performance in a global perspective: evidence from panel data analysis." *International Journal of Logistics Research and Applications*, 21(4), pp.431-443.

Zhu, Q., Sarkis, J., and Lai, K.H. (2012). "Examining the effects of green supply chain management practices and their mediations on performance improvements." *International journal of production research*, 50(5), pp.1377-1394.

Zubin, I., van Arem, B., Wiegmans, B. and van Duin, R. (2020). "Using drones in the last-mile logistics processes of medical product delivery: A feasibility case study in Rotterdam." *Proceedings of the 99th Annual Meeting TRB*, Washington, DC, USA, pp. 12-16.

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