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Application of the Prophet Model in Demand Forecasting and Supply Chain Risk Management for a Packaging Manufacturing Enterprise: A Case Study of TJP Joint Stock Company

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Abstract

In the context of profound global economic integration, enterprises are facing fierce competitive pressures and unpredictable fluctuations from international value chains. The disruptions and market uncertainties in recent years have proven that supply chain management is no longer merely the coordination of the physical flow of goods from manufacturers to consumers. Instead, it has evolved into a data-driven strategic management system, where the ability to respond rapidly and forecast accurately determines an enterprise's competitive advantage. For enterprises like TJP Joint Stock Company, maintaining the balance between supply and demand is a vital problem to ensure competitiveness. To solve this problem, time series forecasting models in general and advanced models like Prophet in particular (developed by Meta) have emerged as an optimal solution due to their robust capability in handling highly seasonal time series data and the effects of holidays and special events. This has opened up a new direction: building an automated, low-cost, yet high-performance and easily operable forecasting system. Concurrently, the study proposes criteria for evaluating the effectiveness of supply chain risk management at TJP Joint Stock Company through an empirical enterprise survey.

Keywords: Prophet Model in Demand Forecasting, Demand Forecasting, Supply Chain Risk Management

1. Introduction

Among current demand forecasting methods, the time series forecasting method emerges as a suitable approach to address complex data characterized by cyclicality, trend, seasonality, and random fluctuations. This is a quantitative method that helps enterprises clearly forecast future customer demand. On the other hand, for packaging manufacturing and outsourcing enterprises like TJP Joint Stock Company, which possess B2B characteristics and rely heavily on customer demand, demand forecasting becomes even more critical in production planning. Therefore, applying a quantitative method to demand forecasting is increasingly urgent, helping to enhance forecasting efficiency and proactiveness for the enterprise.

The Prophet model, developed by Facebook's Data Science team (2017), approaches the forecasting problem using an Additive Model rather than rigorous statistical assumptions. This is one of the models within the time series forecasting method.

The core formula is:

$$[y(t) = g(t) + s(t) + h(t) + \epsilon(t)]$$

- $g(t)$ (Trend): General growth trend, with the ability to automatically detect changepoints.
- $s(t)$ (Seasonality): Multi-period seasonality (weekly, monthly, yearly).
- $h(t)$ (Holidays): The effects of holidays and unexpected events.
- $\epsilon(t)$ (Error): Random error.

The Prophet model demonstrates an outstanding advantage in processing time series data in practical contexts where traditional statistical assumptions are often not guaranteed. Specifically, this model does not require the data to achieve a stationary state and can effectively handle common issues such as missing data or outliers, thereby improving flexibility and applicability in imperfect data environments.

Besides the Prophet model, to increase the objectivity of the research, the authors additionally use two other classical time series forecasting models, ARIMA and SARIMA, to compare the forecasting results, thereby confirming the optimal forecasting model. In which:

The ARIMA (Autoregressive Integrated Moving Average) model is one of the most classic and popular statistical models in time series analysis, introduced by Box and Jenkins (1970). This model forecasts future values based on the linear properties of past values and random errors.

The configuration of ARIMA is specified by 3 main parameters:

[ARIMA (p, d, q)]

- AR (Autoregressive - p): Autoregressive component, representing the dependence of the current value on (p) past values.
- I (Integrated - d): The level of differencing required to transform a non-stationary data series into a stationary one – i.e., removing the trend so that the residuals fluctuate around a mean of zero.
- MA (Moving Average - q): Moving average component, representing the dependence of the current value on (q) past forecast errors.

Academically, the ARIMA model is considered an important reference standard in time series analysis, contributing to affirming the core principle that past values can explain and forecast future behavior through two main mechanisms: inertia and the impact of random noises. This approach lays the foundation for many modern forecasting methods and helps verify the effectiveness of more complex models.

The SARIMA (Seasonal Autoregressive Integrated Moving Average) model is an extension of ARIMA that supports univariate time series data with a seasonal component. The SARIMA model is represented as:

[SARIMA (p, d, q) × (P, D, Q) S]

- (p, d, q): Non-seasonal components.
- (P, D, Q): Autoregressive, differencing, and moving average components specific to the seasonal factor.
- s: The seasonal cycle (e.g., (s = 12) for monthly data, (s = 4) for quarterly data).

From an analytical perspective, the SARIMA model plays an important role in processing time series with seasonal elements by clearly separating short-term trend components and cyclical repeating fluctuations. The extended structure of SARIMA allows simultaneous modeling of both non-seasonal and seasonal factors, thereby improving the ability to accurately reflect the intrinsic characteristics of the data.

Besides applying the Prophet model to forecast packaging outsourcing demand, the research group also discovers the linkage between demand forecasting models and supply chain risk management through demand forecasting errors, which is the premise for risk identification and the interaction among components in the supply chain. Consequently, the research group proposes a procedure for applying the demand forecasting model to supply chain risk management for packaging outsourcing enterprises: Applied at TJP Joint Stock Company.

To enhance the effectiveness of supply chain risk management activities at TJP Joint Stock Company in particular and packaging outsourcing enterprises in general, the research group identifies criteria for evaluating the effectiveness of supply chain risk management at TJP Joint Stock Company.

2. Method

- Collection of secondary data was conducted from domestic and foreign research works, statistical data from the General Statistics Office, the portal of the Ministry of Industry and Trade, and reports from TJP Joint Stock Company. These data form the basis for identifying the enterprise's characteristics and the criteria for evaluating the effectiveness of supply chain risk management.
- Primary data was collected to implement qualitative and quantitative research methods.

For the demand forecasting model, the group collected the enterprise's actual sales data from 2021 to 2025. Then, data preprocessing was conducted: Using code to standardize the data. Next was building and setting up the model by presenting the structure and data of the 3 models: Prophet, SARIMA, ARIMA, and the evaluation indices MAPE and RMSE. Finally, presenting the results of building the demand forecasting model for 12 product codes and comparing the effectiveness of the 3 models Prophet, ARIMA, and SARIMA through the RMSE and MAPE indices.

For the research model on criteria evaluating the effectiveness of supply chain risk management at TJP Joint Stock Company, primary data was collected using two methods: in-depth interviews and employee surveys at TJP Joint Stock Company over a two-month period, starting from March 30, 2026, and ending on May 15, 2026. A total of 105 questionnaires were distributed. Regarding the data processing method, a total of 105 responses were collected. After that, the data was cleaned and included in the study with a sample size of 102 as originally planned. Secondary data was used to identify criteria for evaluating the efficiency of supply chain risk management at TJP Joint Stock Company. After completing the screening process, valid survey forms were coded according to the variable system built in the questionnaire. The data was then entered into SPSS version 26 software through descriptive statistics and reliability testing using Cronbach's Alpha coefficient.

3. Results

3.1 Current state of demand forecasting at TJP Joint Stock Company

The current state of demand forecasting at TJP Joint Stock Company is reflected through demand characteristics in the packaging outsourcing industry and the packaging outsourcing demand forecasting process. Wherein the demand characteristics in the packaging outsourcing industry are expressed through high seasonality, dependence on orders, fluctuations according to the consumer market, and delivery time requirements. The packaging outsourcing demand forecasting process at TJP Joint Stock Company is carried out through 5 sequential steps: Contacting customers before the season; Synthesizing and identifying expected demand; Planning production and supply; Implementing production; Monitoring and adjusting when necessary. It can be seen that the characteristics and process of forecasting packaging outsourcing demand at TJP Joint Stock Company are qualitative, highly dependent on customer order demand, and passive in demand forecasting work. Therefore, the research group proceeds to use a quantitative method in the demand forecasting activities of packaging outsourcing at this enterprise.

3.2 Current state of supply chain risk management activities at TJP Joint Stock Company

Practical research at TJP Joint Stock Company shows that risk management arising from demand forecasting deviations and supply planning is being implemented by the enterprise.

First, regarding risk identification. Currently, TJP Joint Stock Company does not rely on complex quantitative mathematical models, but applies a qualitative approach to identify potential events. This process is operated under the direction of the Board of General Directors combined with the practical experience of key Department Heads.

Second, regarding risk analysis and assessment. To create a premise for control decisions, after establishing the portfolio, the Board of General Directors directs the Divisions to group risks based on a two-variable matrix: financial impact level and probability of occurrence.

Third, risk control and financing mechanisms. The enterprise flexibly applies response measures through the specialized functions of each Division: In terms of control: TJP prioritizes a risk avoidance strategy in operations; In terms of risk financing: This task is primarily assigned to the Accounting department in coordination with the Warehousing department;

It can be affirmed that supply chain risk forecasting and management at TJP Joint Stock Company are still manual, heavily dependent on customer data, and do not yet have high adaptability to market fluctuations.

3.3 Application of the Prophet model in forecasting packaging outsourcing demand at TJP Joint Stock Company

After constructing the 3 time series forecasting models (ARIMA, SARIMA, and Prophet), the research group presents a comparison table of the demand forecasting results of the 3 models as follows:

Table 3.1: Comparison of forecast errors RMSE and MAPE among models

PRODUCT CODE	RMSE			MAPE(%)		
	ARIMA	SARIMA	Prophet	ARIMA	SARIMA	Prophet
SYA-22410-02	631.81	599.54	98.72	40.95	41.84	7.72
SYA-22410-04	69.51	74.93	22.29	11.04	13.14	4.63
SYA-67450-21	461.28	423.3	42.57	36.03	35.94	5.21
SYA-67450-22	554.39	444.04	40.94	41.99	36.18	5.17
SYA-67450-23	131.8	133.84	18.67	18.12	20.42	3.45
SYA-99310-01	570.95	462.95	33.2	39.06	33.96	3.21
TJP-T1001-01	67.06	71.88	27.35	10.98	12.69	5.43
TJP-T1002-01	840.48	1037.56	99.77	34.99	45.81	7.34
TJP-T1003-04	955.3	938.29	93.08	46.34	47.41	8.06
TJP-T1003-11	1058.01	1032.35	88.54	45.1	45.36	7.07
TJP-T1045-01	662.65	570.73	55.59	41.25	38.64	4.35
TJP-T5027-01	121.63	55.61	15.43	18.72	9.09	2.94

Source: Model execution results by the research group 2026

Based on the experimental forecasting results on the dataset comprising 12 product codes of the company, a clear difference in performance between traditional statistical models and the modern model can be observed. The overall results show that the Prophet algorithm has absolute dominance, yielding significantly better results compared to both ARIMA and SARIMA models across all 12/12 tested product codes. This superiority is demonstrated not only in the Root Mean Square Error (RMSE) but also in the stability of the Mean Absolute Percentage Error (MAPE), contributing to higher reliability for production planning.

From the experimental results of building the ARIMA, SARIMA, and Prophet models based on the sales data file at TJP Joint Stock Company, it shows that the Prophet model holds absolute dominance in forecasting effectiveness and stability based on model evaluation metrics.

3.4 Criteria for evaluating the effectiveness of supply chain risk management at TJP Joint Stock Company

The research indicates that there are 5 evaluation criteria impacting the Effectiveness of supply chain risk management at TJP Joint Stock Company.

With a standardized coefficient (Beta) of 0.443, the criterion Risk forecasting and identification capability (DB) has the greatest impact on Supply chain risk management effectiveness. Data analysis results show this criterion has a standardized coefficient = 0.443 and Sig = 0.000 (< 0.05), which means that when the criterion "Risk forecasting and identification capability" changes by 1 unit, "Supply chain risk management effectiveness" will also change in the same direction by 0.443 units. This can be explained that at TJP Company, proactively identifying potential risks early is the key to success in risk management.

The second most impactful evaluation criterion is Supply source and supply chain operation stability (OC). With a standardized coefficient of 0.283 and Sig = 0.000 (< 0.05), it means that when the criterion "Supply source and supply chain operation stability" changes by 1 unit, "Supply chain risk management effectiveness" will also change in the same direction by 0.283 units. This shows that operational stability helps the enterprise handle supply disruptions in a timely manner.

Next is the criterion Financial performance (TC) with the third largest impact. The analysis results show this criterion has a standardized coefficient = 0.270 and Sig = 0.000 (< 0.05), meaning that when other criteria remain unchanged, if "Financial performance" increases by 1 unit, "Supply chain risk management effectiveness" will also increase in the same direction by 0.270 units. This result reflects that a solid financial foundation provides sufficient resources for the enterprise to respond flexibly to risks.

The fourth evaluation criterion is Supply chain response and recovery capability (UP). The analysis results yield a standardized coefficient = 0.215 and Sig = 0.002 (< 0.05), meaning that when the criterion "Supply chain response and recovery capability" changes by 1 unit, "Supply chain risk management effectiveness" will also change in the same direction by 0.215 units. Any effort to improve recovery flexibility contributes positively to overall management effectiveness.

Finally, the Inventory and operational efficiency (TK) criterion has the lowest level of impact but still ensures statistical significance. With a standardized coefficient of 0.180 and Sig = 0.010 (< 0.05), this means that when the criterion "Inventory and operational efficiency" changes by 1 unit, "Supply chain risk management effectiveness" will change in the same direction by 0.180 units. Efforts to optimize warehousing continue to contribute positively to overall risk management effectiveness.

Table 3.2: Conclusions of research hypotheses and the impact level of evaluation criteria on Supply chain risk management effectiveness at TJP

Research Hypothesis	Conlusion
Hypothesis H1: Forecasting and risk identification capability (DB) has a positive impact on Supply Chain Risk Management Effectiveness.	**Accepted**, with a standardized Beta coefficient of **0.443**.
Hypothesis H2: Supply stability and supply chain operations (OC) have a positive impact on Supply Chain Risk Management Effectiveness.	**Accepted**, with a standardized Beta coefficient of **0.283**.
Hypothesis H3: Inventory and operational efficiency (TK) have a positive impact on Supply Chain Risk Management Effectiveness.	**Accepted**, with a standardized Beta coefficient of **0.180**.
Hypothesis H4: Supply chain responsiveness and recovery capability (UP) have a positive impact on Supply Chain Risk Management Effectiveness.	**Accepted**, with a standardized Beta coefficient of **0.215**.
Hypothesis H5: Financial performance (TC) has a positive impact on Supply Chain Risk Management Effectiveness.	**Accepted**, with a standardized Beta coefficient of **0.270**.

Source: Compiled by the authors from survey data analysis results

It can be seen that the analysis results confirm all 5 proposed criteria have a positive impact and statistical significance (Sig. < 0.05) on Supply chain risk management effectiveness. This indicates that risk management at TJP Joint Stock Company is a systematic process, requiring synchronized coordination from forecasting, ensuring supply, maintaining finance to operations, inventory, and recovery capabilities. Among them, the criterion "Risk forecasting and identification capability" (DB) has the most positive impact on "Supply chain risk management effectiveness".

4. Discussion and Conclusion

4.1 Discussion

This study was conducted with the objective of optimizing demand forecasting and supply chain management at TJP Joint Stock Company through the construction of a demand forecasting system. Through the implementation process from model experimentation to solution design, the study achieved the following key results:

Regarding research content: The authors compared and evaluated popular time series forecasting models and determined that Prophet is the most optimal model for the specific characteristics of the enterprise's data. On that basis, the study actualized the model into a closed forecasting system integrating Google Sheets and Google Colab. The system fully automated the data flow from collection, preprocessing (ETL), model training to exporting forecasting results for the next 06 months. Validation metrics such as RMSE and MAPE affirmed the high reliability and accuracy of the system in supporting decision-making. In addition, the research group proposed criteria for evaluating the effectiveness of supply chain risk management at TJP Joint Stock Company to enhance the efficiency of this activity.

Contributions and applicability of the project:

(1) Regarding research methodology: The project successfully combined machine learning techniques with popular cloud computing tools. The novel contribution is demonstrated in building an automated ETL process that connects spreadsheet data with Python's high-performance computing environment without incurring infrastructure costs.

(2) Regarding theory: The study contributes to systematizing the theoretical framework on the application of the Prophet model in enterprise demand forecasting. Simultaneously, the project clarifies the role of the "open ecosystem" in bridging the gap between complex mathematical theory and practical application in enterprises.

(3) Regarding practice: The study directly solved the forecasting problem at TJP Company, providing a quantitative forecasting picture instead of relying on intuitive experience. This is a valuable reference model for small and medium-sized enterprises (SMEs) in Vietnam in low-cost digital transformation.

(4) Regarding applicability: The project's outcome is a complete system, easy to operate for personnel without programming expertise. The system can be used as internal training material for the supply planning department and as a reliable database for the board of directors in budget and inventory planning.

4.2 Conclusion

Based on the research results, the authors make several recommendations to improve the system's operational efficiency at TJP Joint Stock Company as follows:

a) For the Board of Directors of TJP Joint Stock Company

Standardize the data entry process: For the system to operate stably, the company needs to establish regulations for updating data into the Du_lieu_Goc spreadsheet periodically and accurately. Any deviation in time or unit of measurement at the input directly affects the final forecasting results.

Invest in human resource training: Encourage the Logistics and Sales departments to participate in basic training courses on data thinking and how to exploit results from the system to coordinate smoothly in supply planning.

b) For the technical and system operation department

Periodically optimize model parameters: Due to the constantly fluctuating nature of the market, the operations team needs to re-evaluate Prophet's seasonal parameters after every quarter to ensure the model always "learns" the latest consumer trends.

Deploy backup forecasting models: It is recommended to apply scenario-based forecasting mechanisms based on upper and lower bound confidence intervals. This helps the enterprise prepare for both sudden drops and spikes in demand.

Integrate Dashboards: In the next phase, results from Google Sheets should be connected with visualization tools like Google Looker Studio to create real-time reports, making the monitoring of demand fluctuations more intuitive and vivid.

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