Machine learning approach for optimizing healthcare Supply chain

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ABSTRACT

Supply Chain Management (SCM) is a sequence of business activities from suppliers through customers, product decisions, services, and information to achieve customer satisfaction. SCM in healthcare (HSCM) involves the efficient movement of medicines, medical or surgical equipment, and other products. As per the Premier health survey, SCM costs consistently rank as some of the most significant healthcare and hospital systems expenses. The top priority of healthcare leaders is to estimate and reduce healthcare supply chain costs. The assessment of HSCM is essential to bridge the gaps using potential Machine Learning (ML) techniques and improve the modern healthcare system. A detailed systematic literature review (SLR) was performed to gain more insights into the technological innovations, which highlighted the vulnerabilities of HSCM and provided valuable measures to make it cost-effective. We followed a five-step process, which included a pilot search in the first phase to obtain a better grasp of the present literature, develop criteria for literature selection, and formulate the research topic and subsequent steps. Based on the exploratory SLR results we consider the primary research question for investigation: How do ML techniques play a significant role in the HSCM system process by predicting the freight cost and thereby reducing the cost of the healthcare supply chain? The essential contributions of this ongoing research paper include an Exploratory Data analysis(EDA) of HSCM data and applying a Supervised ML approach to determine freight cost. The dataset used in this research study is obtained from the United States Agency for International Development. The dataset contains 33 features and 10325 observations, both numeric and categorical. We have used SLR by exploring multiple databases (IEEE, Science Direct, Research Gate, etc.) with specific keywords of predictive supervised ML (Linear and Non-Linear regression) algorithms to predict freight cost. The model is trained based on the United States Agency for International Development (USAID) data. Finally, the evaluation uses different performance measures and prediction of freight cost.

KEYWORDS

Supply chain management, Healthcare supply chain management, Machine learning, Regression analysis, Systematic Literature Review

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1 INTRODUCTION

Supply Chain Management (SCM) is a sequence of business activities from suppliers through customers decisions that provide the product, services and information to achieve customer satisfaction. It involves activities utilized to efficiently integrate suppliers, manufacturers, warehouses, transporters, retailers, and customers so that the right product or service is distributed at the right quantities, to the right locations, and at the right time, in order to minimize system-wide costs while satisfying customer service level requirements. The main objective of SCM is to achieve sustainable competitive Advantage.

A larger emphasis on services has grown as the supply chain management (SCM) and information technology disciplines have lately evolved. There is a significant growth in Information Communication Technology(ICT) applications across the healthcare industry in the recent days such as (Clinical decision support,computerized disease registries, Electronic medical record system). However, little is known about the current status of research in healthcare SCM. There is a scarcity of focused studies on the Healthcare Service Industry Supply Chain Management (HCSCM) and the various evolving ICT applications within the healthcare supply chain.

This paper aims to investigate the current trends, progress, and the challenges in the healthcare supply chain industry using a detailed Systematic Literature Review (SLR) and then create a noble approach for current health care managers by reviewing previous research frameworks proposed in this field.

We have conducted an extensive SLR and propose a supervised Machine Learning (ML) model for predicting the freight cost for the supply chain transactions considering the features (insurance charges,line item value, line item quantity, and weight etc.). This model not only helps to predict the freight cost of transactions, but also bridges the gaps in the heath care supply chain management by helping reduce the freight cost. To do systematic literature review, we have conducted pilot search and came up with with the following potential research question.

1.1 Research Question

How do ML techniques help healthcare Supply chain management process by predicting the freight cost and thereby reducing the cost of healthcare supply chain?.

Important Contributions: The important contributions of this research paper are as follows:

- Supervised Machine learning approach to determine freight cost.
- Exploratory data analysis(EDA).
- Independent variable set suggestion to determine freight cost.

1.2 Supply chain trends

This subsection details the trends in supply chain management. The global trends and key factors in supply chain management were studied by Rajagopalan[17].

1.2.1 Demand planning. As manufacturing sources and capacities have grown, many organizations are shifting their efforts away from plant-level production planning and towards a demand-driven focus, attempting to influence and manage demand more efficiently. Advanced demand planning systems and appropriate tactics can also aid in the discovery of data and the identification of patterns buried in a company's data systems.

1.3 Globalization

Globalization is having a significant impact on how company is handled an d transacted, even at the most local levels, thanks to improvements in communications. The supply chain is the part of a company that is most affected by the move towards a global business environment. The increased integration of a global customer and supplier base has had a significant impact on manufacturing, distribution, material sourcing, invoicing, and returns, and many companies are finding that their existing processes and technology are not flexible enough forth is new business environment.

1.4 Increased competition and price pressures

Due to the ongoing commoditization of many items, businesses must find new ways to differentiate themselves. Prices for several of a large global consumer goods manufacturer's staple products fell by as much as 60-80 percent on one occasion. They could no longer fetch a higher market price due to product innovation and brand equity. They made considerable cost improvements through the supply chain re-design and technology in order to compete with that commoditized product.

1.5 Outsourcing

Some people recognize that outsourcing parts or the entire supply chain can be beneficial. Companies are reaping further synergies by outsourcing all or parts of their supply chain as the marketplace improves around (1) information media and systems, (2) cost and quality of global manufacturing and distribution, and (3) product design capabilities.

1.6 Shortened and more complex product life cycles

Many multinational corporations (MNCs), transnational corporations (TNCs), and international business corporations (IBCs) are under pressure to produce novel products and get them to market faster. Companies require more effective product lifecycle management systems to suit the needs of both customers and consumers. This involves a strong focus on new product launch, product discontinuance, design for manufacturability, and leveraging across all product and infrastructure features.

1.7 Collaboration between stakeholders' customers and suppliers

Beyond linking information systems, the level of collaboration extends to fully integrating business processes and organizational structures among enterprises that make up the entire value chain. The ultimate goal of cooperation is to improve visibility across the value chain in order to make better management decisions and, as a result, lower value chain expenses.

2 SEARCH CRITERIA FOR LITERATURE REVIEW

This study used a comprehensive, evidence-based literature review strategy. Figure 1 shows the steps used in the SLR process.

We followed five steps, which included a pilot search in the first phase to obtain a better grasp of the present literature, develop criteria for literature selection, and formulate the research topic and subsequent steps. As a result, we used a five-step systematic review process.

2.1 Database selection

We explored the following databases for the SLR study.

- IEEE
- Mendeley
- Science Direct
- Springer

2.2 Search Strings

The search strings that we used for the search process are as follows: "Healthcare Supply chain" "Supply chain management" "Machine learning in Supply chain" "Machine learning in Healthcare" "Linear regression for Healthcare Supply chain" "Ensemble techniques for Healthcare Supply chain"

sub

3 STUDY SELECTION AND EVALUATION

To guarantee that publications using various taxonomies were detected, the primary search phrases were fairly broad. We found articles using the inclusion and exclusion criteria from the pilot search[20]. The first criterion focuses on the literature's time range, which is between 2007 and 2021, because the majority of papers, as well as a considerable number of new trends and applications, have developed during this time.The second criterion focuses on relevance and quality: only peer-reviewed journal and conference papers were considered for the review, excluding book reviews, chapters, case reports, discussions, and news articles;additionally, each paper was read by two authors to ensure that it met the required standards of quality.

The primary study articles selected to be used for this research and important keywords and the techniques discussed in the primary studies are listed in Table 1.

4 METHODOLOGY

The flowchart shown in Figure 2 depicts the diagrammatic representation of the ML process.

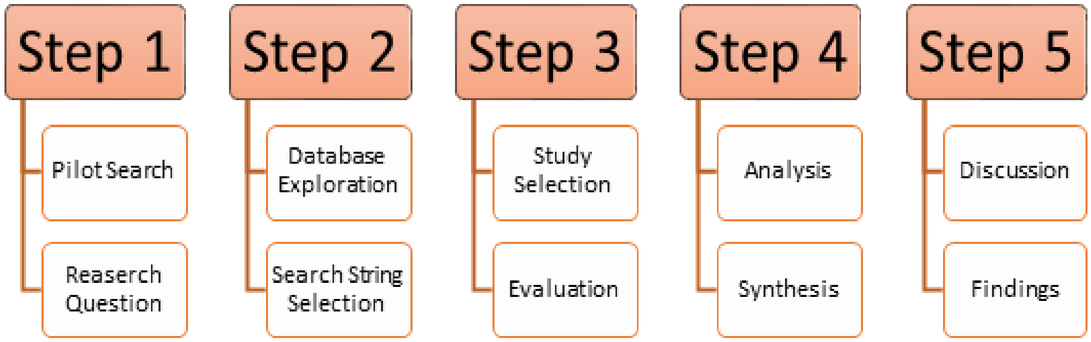

Figure 1: Steps in Systematic Literature Review

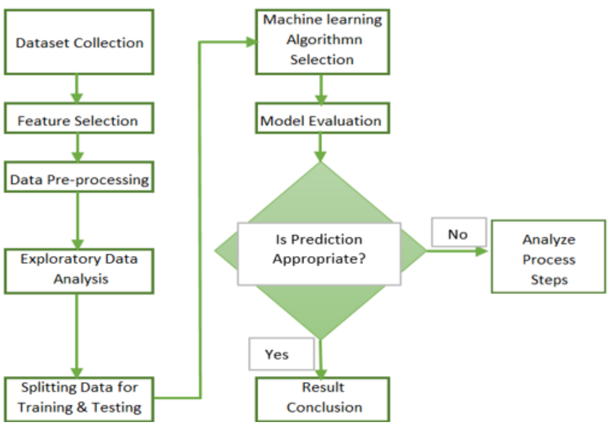

Figure 2: Flowchart for ML Process

4.1 DATA COLLECTION

Following the detailed SLR study, the potential challenges and the requirement of advanced techniques to study the impact that supply chain management has on global economy and business. The data used in this paper is obtained from United States Agency for International Development. Data-set contains 33 features and 10325 observations which are both numeric and categorical in nature. For modelling relevant variables have chosen based on past study and domain based criteria and by using EDA results, hence total variables step down from 33 to 11 for models fitting.

5 VARIABLE SELECTION

The following subsections list the variable selection criteria used in the study.

5.1 Dependent Variable selection:-

Based on the following parameters we have selected our dependent variables, which is the freight cost.

- Goal Oriented
- Literature Review Research
- Research Question Based

5.2 Independent Variable Selection

The independent variables are selected using the following constraints.

- Goal Oriented
- Literature Review Research
- Research Question Based
- Domain Expert knowledge
- EDA(Pearson Correlation, Scatter plot, Variation Inflation Factor(VIF))

The consideration while selecting Independent variables are as follows:

Multiple Linear Regression Assumption

- Relationship between output (Y) and feature (X) must be linear.
- Features (X1, X2, ..., Xn) must be independent from each other i.e., there is no multicollinearity.
- Residuals distribution should be normal.

Measures to check linearity between Y and X as well collinearity among independent variables.

- Pearson Correlation Matrix
- Scatter plot
- Variance Inflation Factor

To deal with collinearity and non-linearity there are some methods that we used as are listed below.

- Regularization
- Transformation

The set of variables which have selected for training our model with their respective definitions are listed in Table 2

6 DATA PREPROCESSING

The data is cleaned and preprocessed at first to ensure that there are no flaws in the data, such as noise, redundancy, or missing data, that could impair the model's overall performance.Data preparation,data wrangling is must to transform raw data into the suitable data which can be readily used for modeling.In our data set, we have handled missing values and noise by removing observations.Also, we have converted categorical value to numerical value by label encoding.

- Identifying gaps in data, gaps can be missing values or some abstract.

Table 1: detailed

S.no.	Primary Study	Keywords	Tool/Techniques Used
1	E. Sreehari and S. Srivastava (2018)[18]	Regression, simple linear regression, prediction, correlation coefficient.	Multiplear Linear Regression
2	C. Dongdong (2009)[5]	Supply Chain, Support Vector Machine	Support Vector Regressor
3	K.D. Kankanamge et al.(2019)[13]	Time Series Analysis, Travel Time Prediction, XGBoost Regression	XGBoost Regressor
4	A. W. A. Gendy and A. Lahmar (2019)[7]	Health care supply chain, Hospital, Supply chain management, Supply Chain Performance,Healthcare Inventory management, literature review.	
5	G. K. Getele et al.(2020)[8]	Healthcare organizations, Health service (HS) management, healthcare quality, supply chain management (SCM)	
6	R. Harikrishnakumar et al (2016)[11]	Supplier assessment, classification algorithms, machine learning	Classification techniques
7	F. F. Jahantigh and B. Malmir (2015)[12]	Supply chain management (SCM), Healthcare systems, Inventory	
8	P. M. Shijith Kumar et al. (2018)[16]	health care supply chain, physician-manager disconnect, physician engagement.	1.Strategic Purchasing, 2. Purchasing officer – Physician Dynamics
9	M. Bvuchete et al. (2018)[4]	Supply chain, Medical services, Planning, Collaboration, Radiofrequency identification, Monitoring,Supply chain management	Vodacom/Mezzanine ware Stock Visibility Solution (SVS)
10	Y. Han and L. Wei (2018)[10]	product supply chain; GPO; demand; revenue sharing; power schemes	Numerical Simulation
11	R. Toorajipour et al. (2021)[19]	Artificial intelligence; Supply chain management; Systematic literature review	
12	A. Brnabic and L.M. Hess (2021)[3]	Machine learning, Decision making, Decision tree, Random forest, Automated neural network.	
13	K. Govindan et al. (2020)[9]	Disaster management; Epidemic outbreaks; Healthcare supply chain disruption mitigation; Fuzzy inference system; COVID-19	Fuzzy Inference System
14	L. Gao et al. (2019)[6]	healthcare supply chain network; medical insurance reimbursement strategies; reference price effect; game theory; patient choice behavior	
15	A. Lucchese et al. (2019)[15]	Healthcare supply chain management; Facility Location Problem; Location Routing Problem; hub; spoke network; Centralized healthcare system	
16	D. Kritchanchai et al. (2012)[14]	supply chain management, healthcare supply chain, standard drug code	
17	K. Rajagopalan (2016)[17]	Supply Chain Mangement and Challenges	
18	Y. Zhou et al. (2021)[21]	Fraud prediction model based on XGBoost	XGBoost
19	C. Zamiela et al. (2020)[20]	Resilience; COVID-19; Healthcare supply chain; Preference Selection Index (PSI); Proximity Indexed Value (PIV); Cluster analysis; Unsupervised machine learining; Rank reversal	
20	V. Arya et al. (2015)[1]	Supply Chain; Healthcare; Collaboration; Alliance; High Technology; Dental Implants.	
21	N. Armal et al. (2007)[2]	Multiple Linear Regression, polynomial terms.	Multiplear Linear Regression

- Scaling of data.
- Merging of data from multiple data sources.
- Removing redundant columns
- Conversion of categorical variables into numeric variables.
- Checking of extreme values or outliers.

Table 2: Attributes Selection for ML Model

S.No.	Attributes	
	Dependent Variable	
1	Freight Cost (USD)	Freight charges associated with all lines.
	Independent Variables	
1	Fulfill Via	Method through which the shipment was fulfilled.
2	Vendor INCO Term	The vendor INCO term (also known as International Commercial Terms) for Direct Drop deliveries.
3	Shipment Mode	Method by which commodities are shipped
4	Unit of Measure (Per Pack)	Pack quantity (pills or test kits) used to compute unit price
5	Line Item Quantity,	Total quantity (packs) of commodity per line item
6	Line Item Value	Total value of commodity per line item
7	Pack Price	Cost per pack.
8	Unit Price	Cost per pill (for drugs) or per test (for test kits)
9	Weight (Kilograms)	Weight for all lines.
10	Line Item Insurance (USD)	Line item cost of insurance, created by applying an annual flat rate ( ) to commodity cost

7 EXPLORATORY DATA ANALYSIS

Data Visualization or exploratory data analysis(EDA) is one of the important step to know which independent variable is more supportive to predicting variable. Usually model predicts some results or values, the model doesn't tell you how to manage your values, so here EDA can help to know which attribute is affecting your result or how it will affect you. Below are some charts to do EDA.

In Figure 3, the heatmap shows pearson correlation coefficient values between dependent variable and independent variables as well as values among independent variables with each other.

Correlation coefficients are used to measure the strength of the linear relationship between two variables. A correlation coefficient greater than zero indicates a positive relationship while a value less than zero signifies a negative relationship.The possible range of values for the correlation coefficient is -1.0 to 1.0.If the correlation coefficient of two variables is zero, variables are said to have no linear relationship.

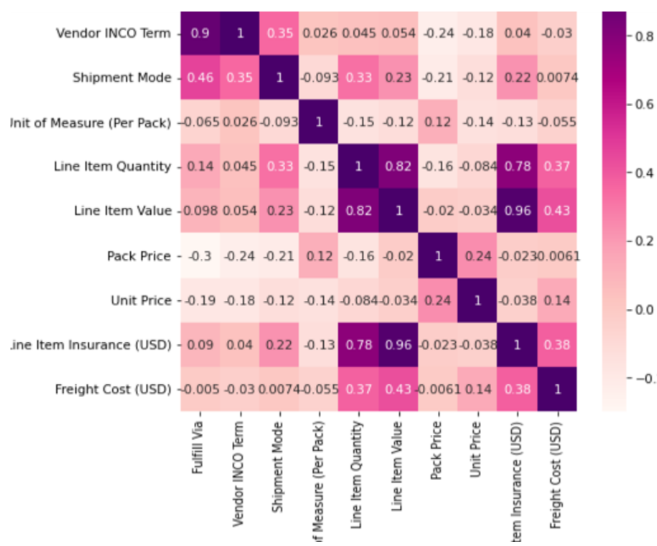

Figure 3: Heatmap showing correlation

8 MODEL DEVELOPMENT

With the existing data set, we have done our research twice to get more meaningful results. In the first iteration, we have used multiple linear regression and in the second iteration, we have used non-linear regression or better to say ensemble method extreme gradient boosting (XGBoost) to reduce the bias and variance, to get better predictions results.

- **Multiple Linear Regression(MLR)**
  Regression analysis is a modelling technique for analysing the relationship between a continuous (real-valued) dependent variable y and one or more independent variables k $x_1, x_2, ..., x_k$. The goal in regression analysis is to identify a function that describes, as closely as possible, the relationship between these variables so that the value of the dependent variables can be predicted using a range of independent variables values. The multiple linear regression equation can be expressed in the form [6]:

$$y = \beta_o + \beta_1 x_1 + \beta_2 x_2 + ... + \beta_k x_k + \epsilon$$

  - y is the dependent variable
  - x1,x2,.....xk are independent variables
  - Bo is the intercept of the regression line,
  - B1 is the slope of the regression line
  - ϵ is an error term.

- **Extreme Gradient Boosting (XGBoost)**

  Gradient boosting is a type of ensemble machine learning method that may be used to solve classification and regression predictive modeling problems.

- **Decision Trees**

  Decision tree models are used to create ensembles. To repair the prediction mistakes caused by past models, trees are introduced to the ensemble one at a time and fitted. The boosting model is a sort of ensemble machine learning model.

9 MODEL VALIDATION

To evaluate the performance of our model, we have shown result of below measures.

- **R square**:- is a statistical measure of fit that indicates how much variation of a dependent variable is explained by the independent variable(s) in a regression model. The ideal value of r-square is 1.The closer the value of r-square to 1, the better is the model fit.

$$\textbf{R Squared} = 1 - \frac{SS_{Residual}}{SS_{Total}}$$

  - SS-residual is the residual sum of squares.
  - SS-total is the total sum of squares..

- **Mean Absolute Error (MAE)**:- In statistics, mean absolute error (MAE) is a measure of errors between paired observations expressing the same phenomenon.

$$\textbf{Mean Absolute Error} = \frac{\left|(y_i - y_p)\right|}{n}$$

  - yi is the actual value
  - yp is the predicted value
  - n = number of observations

- **Mean squared error (MSE)**:- The mean squared error tells,how close a regression line is to a set of points.

$$\textbf{Mean Squared Error} = \frac{\sum (y_i - y_p)^2}{n}$$

  - yi is the actual value
  - y-hat is the predicted value
  - n = number of observations

- **Root mean square error (RMSE)**:- RMSE can be known as root mean square error or root mean square deviation. It can be used measure of difference between sample and population values.

$$\textbf{Root Mean Squared Error} = \sqrt{\frac{\sum_{i=1}^{n} (y_i - \hat{y})}{n}}$$

  - yi is the actual value
  - y-hat is the predicted value
  - n = number of observations

10 EXPERIMENTAL RESULTS AND FINDINGS

The model performance results are shown in Table 3.

In the first iteration, we have used multiple linear regression and got the r-square value of 0.20 which is equivalent to a model with 20 percent accuracy, so it indicates the linear regression model does not fit on this dataset or more specifically on these set of variables. Hence to improve our model prediction we have used the ensemble technique which can be considered as the non-linear regression.

In the Second iteration, we have used the XGBoost ensemble method and got an r-square value of 0.48, this method has improved our prediction more than twofold.

- As per Zikmund, William (2000) mentioned in business research methods 6th edition , if R-squared value lies between 0.3 < r < 0.5 then this value is generally considered a weak or low effect size.
- if R-squared value lies between 0.5 < r < 0.7, it is considered as moderate, and
- if it is greater than this value is generally considered as strong effect size.

Hence use of another data-set will be the next step of this study.

11 CONCLUSION AND FUTURE WORK

In our study, we have proposed a supervised learning and ensemble method based freight cost framework to determine potential variables set which can better predict freight cost by using machine learning techniques. In this paper, we have developed a multiple regression model in first iteration and ensemble model in second iteration that provides a suitable framework for identifying the right set of variables along with the right identification of the algorithm. For the future work, bigger dataset can be used to train and test the performance of the model when subjected to a high level of complexity. Furthermore, we plan to investigate other optimization algorithms that can yield a better performance.

REFERENCES

[1] 2015. High Technology Health Care Supply Chains: Issues in Collaboration. *Procedia - Social and Behavioral Sciences* 189 (2015), 40–47. https://doi.org/10.1016/j.sbspro.2015.03.190 Operations Management in Digital Economy.

[2] N. Amral, C. S. Ozveren, and D. King. 2007. Short term load forecasting using Multiple Linear Regression. In *2007 42nd International Universities Power Engineering Conference*. 1192–1198. https://doi.org/10.1109/UPEC.2007.4469121

[3] Alan Brnabic and Lisa M. Hess. 2021. Systematic literature review of machine learning methods used in the analysis of real-world data forhttps://www.overleaf.com/project/61e73fedda6a1731acb44ef4 patient-provider decision making. *BMC Medical Informatics and Decision Making* 21 (2021). https://doi.org/10.1186/s12911-021-01403-2

[4] Munyaradzi Bvuchete, Sara. S Grobbelaar, and Joubert Van Eeden. 2018. A case of healthcare supply chain visibility in South Africa. In *2018 3rd Biennial South African Biomedical Engineering Conference (SAIBMEC)*. 1–5. https://doi.org/10.1109/SAIBMEC.2018.8363179

[5] Chen Dongdong. 2009. An effective supply chain performance prediction method and its application. In *2009 IEEE International Conference on Grey Systems and Intelligent Services (GSIS 2009)*. 651–654. https://doi.org/10.1109/GSIS.2009.5408233

[6] Lingyu Gao and Xiaoli Wang. 2019. Healthcare Supply Chain Network Coordination Through Medical Insurance Strategies with Reference Price Effect. *International Journal of Environmental Research and Public Health* 16, 18 (2019). https://www.mdpi.com/1660-4601/16/18/3479

[7] Ahmad Wassim Al Gendy and Arij Lahmar. 2019. Review on Healthcare Supply Chain. In *2019 IEEE/ACS 16th International Conference on Computer Systems and Applications (AICCSA)*. 1–10. https://doi.org/10.1109/AICCSA47632.2019.9035234

[8] Gutama Kusse Getele, Tieke Li, and Jean Tsitaire Arrive. 2020. The Role of Supply Chain Management in Healthcare Service Quality. *IEEE Engineering Management Review* 48, 1 (2020), 145–155. https://doi.org/10.1109/EMR.2020.2968429

[9] Kannan Govindan, Hassan Mina, and Behrouz Alavi. 2020. A decision support system for demand management in healthcare supply chains considering the epidemic outbreaks: A case study of coronavirus disease 2019 (COVID-19). *Transportation Research Part E: Logistics and Transportation Review* 138 (2020), 101967. https://doi.org/10.1016/j.tre.2020.101967

[10] Yin Han and Lingyun Wei. 2018. A study on healthcare-product supply chain with a group purchasing organization. In *2018 5th International Conference on Industrial Engineering and Applications (ICIEA)*. 67–71. https://doi.org/10.1109/IEA.2018.8387072

[11] Ramkumar Harikrishnakumar, Alok Dand, Saideep Nannapaneni, and Krishna Krishnan. 2019. Supervised Machine Learning Approach for Effective Supplier Classification. In *2019 18th IEEE International Conference On Machine Learning And Applications (ICMLA)*. 240–245. https://doi.org/10.1109/ICMLA.2019.00045

[12] Farzad Firouzi Jahantigh and Behnam Malmir. 2015. Development of a supply chain model for healthcare industry. In *2015 International Conference on Industrial*

Table 3: Performance Evaluation of ML Techniques

1st Iteration	**R2 Score**	**MAE**	**MSE**	**RMSE**
(Linear Regression)	0.20	7858.3	206576457.5	14372.8
2nd Iteration	**R2 Score**	**MAE**	**MSE**	**RMSE**
(Non-Linear Regression - XGBoost)	0.48	5628.7	143175668.9	11546.5

Engineering and Operations Management (IEOM). 1–5. https://doi.org/10.1109/IEOM.2015.7093935

[13] Kusal D. Kankanamge, Yasiru R. Witharanage, Chanaka S. Withanage, Malsha Hansini, Damindu Lakmal, and Uthayasanker Thayasivam. 2019. Taxi Trip Travel Time Prediction with Isolated XGBoost Regression. In *2019 Moratuwa Engineering Research Conference (MERCon)*. 54–59. https://doi.org/10.1109/MERCon.2019.8818915

[14] Duangpun Kritchanchai. 2014. A Framework for Healthcare Supply Chain Improvement in Thailand. *Operations and Supply Chain Management: An International Journal* 5, 2 (2014), 103–113. https://doi.org/10.31387/oscm0120080

[15] Andrea Lucchese, Antonella Marino, and Luigi Ranieri. 2020. Minimization of the Logistic Costs in Healthcare supply chain: a hybrid model. *Procedia Manufacturing* 42 (2020), 76–83. https://doi.org/10.1016/j.promfg.2020.02.025 International Conference on Industry 4.0 and Smart Manufacturing (ISM 2019).

[16] Shijith Kumar PM, Maria Sabastin Sagayam, Aravind Janardhanan, and Lakshmi Sanjeev. 2018. Performance and Purchasing effects of Healthcare Supply Chain. In *2018 International Conference on Advances in Computing, Communications and Informatics (ICACCI)*. 2011–2017. https://doi.org/10.1109/ICACCI.2018.8554433

[17] Kamal Rajagopalan. 2016. GLOBAL TRENDS IN SUPPLY CHAIN MANAGEMENT. *Journal of Business Economics and Management* 6 (01 2016), 99–112.

[18] E. Sreehari and Satyajee Srivastava. 2018. Prediction of Climate Variable using Multiple Linear Regression. In *2018 4th International Conference on Computing Communication and Automation (ICCCA)*. 1–4. https://doi.org/10.1109/CCAA.2018.877745

[19] Reza Toorajipour, Vahid Sohrabpour, Ali Nazarpour, Pejvak Oghazi, and Maria Fischl. 2021. Artificial intelligence in supply chain management: A systematic literature review. *Journal of Business Research* 122 (2021), 502–517. https://doi.org/10.1016/j.jbusres.2020.09.009

[20] Christian Zamiela, Niamat Ullah Ibne Hossain, and Raed Jaradat. 2021. Enablers of resilience in the healthcare supply chain: A case study of U.S healthcare industry during COVID-19 pandemic. *Research in Transportation Economics* (2021), 101174. https://doi.org/10.1016/j.retrec.2021.101174

[21] Yichun Zhou, Xuyang Song, and Mengyuan Zhou. 2021. Supply Chain Fraud Prediction Based On XGBoost Method. In *2021 IEEE 2nd International Conference on Big Data, Artificial Intelligence and Internet of Things Engineering (ICBAIE)*. 539–542. https://doi.org/10.1109/ICBAIE52039.2021.9389949