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An Approach for Analysis of Supply Chain Management using Machine Learning

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Abstract:

The rapid evolution of the supply chain ecosystem in recent years is largely attributable to the widespread use of digital technologies in business and industry. To say that machine learning is at the heart of this transformation would be an understatement. It has had a profound impact on the workings of organizations by facilitating new forms of communication, automating formerly manual tasks, elevating the importance of digital records, etc. Supply chain management is becoming more important as companies strive to stand out in an era of shrinking profit margins and increasingly discerning customers. Strategic, tactical, and operational Supply Chain management and optimization based on data. In such a data-rich environment, machine learning methodologies and techniques have various applications in supply chain decision-making. Today, Machine Learning technologies are ubiquitous, and no organization can afford to ignore them. This fact becomes glaringly obvious in highly competitive markets. We explore the potential applications of machine learning techniques for supply chain management in this paper. The fundamental motivation for this research is to determine whether or if machine learning techniques may be integrated into the existing toolkit available to supply chain decision-makers for better exploitation of the massive volumes of data now being generated by the supply chain.

Keywords-- Supply chain,Supply network, Expert system,Machine Learning,Digital Transformation, Supply Chain Analytics.

1. Introduction:-

We have been fighting the whole globe for our right to be unique for hundreds of years now. One of the most persuasive and beneficial results of this modernisation is the paved road via natural resources that crosses the waste management and remanufacturing sectors. Recycling garbage has been a hot topic among environmentalists for decades. Remanufacturing. the bedrock of industrialization, will always be able to fuel the expanding economy, even in this fourth revolution period when automation, digital technology, and the global supply chain are gaining significance. In cases when there is a scarcity of a necessary raw material due to ongoing resource depletion, recycling is the only viable option for maintaining ecological equilibrium and minimising waste. The exploitation of human resources is what makes possible the scientific and technological advances that benefit society and the economy. The human mind, its efficiency, and its experience have radically altered our view of the universe as a whole. For the sake of the environment and commercial enterprises, this thesis seeks to reduce the impact of human error on recycling networks.

Supply chain management is the process of coordinating the steps involved in producing a product from start to finish, from sourcing raw materials to shipping completed items to wholesalers and retailers. These tasks are broken up and given to several departments. In a supply chain, the product flow is the forward flow, while the reverse flow involves money and data. The goal of every supply chain is to reduce the total cost of the system, and supply chain management uses this data and these resources to coordinate the various steps in the supply chain in order to do so. These steps include determining where to place orders, when to place orders, where to manufacture goods, how to obtain the most efficient transportation routes, how to transport finished goods, where to trade goods, etc. To maintain consumer satisfaction and loyalty, a successful supply chain must use efficient tactics for meeting market demand, maintaining a stable supply, and setting prices at the optimal level. Supply chain management is a discipline that has benefited many well-known businesses like Apple, Dell, etc. In a case study, it was shown that the use of supply chain tactics had a positive effect on the firm's bottom line. Apple is a prominent American multinational technology corporation known for producing personal computers, computer software, cellphones, etc. According to their 2010 annual report, retail shop sales increased by almost 47% over the previous year, totaling around $10 billion (Chopra & Meindl, 2013). Their predicted growth in sales has reached $274.5 billion at this point.

Since machine learning may aid in the optimisation of routine tasks, it has been of tremendous use in the industrial sector. Supply chain management and optimisation have been impacted by technological advancements. Machine learning (ML) has facilitated the ability of supply chain managers to recognise trends and zero in on the factors that affect the efficiency of the network as a whole. Organisations that want to either increase the efficiency of their supply chains or keep things as they are now need to keep an eye on the data in search of new trends. With the help of supply chain ML, a process that used to need human or semi-human labour is now fully automated. Data from supply networks is continuously analysed by machine learning algorithms. This tool assists firms in identifying areas where supply chain operations might be improved. With the help of algorithms and constraint-based modelling, a number of elements that have an impact on the functioning of the supply chain may be identified and taken into consideration with greater precision and efficiency. Accuracy Many aspects of supply chain management may be learnt with the use of AI and ML, including supplier quality, stock levels, demand estimations, procurement, product planning, and logistics management. Potential implications for Supply Chain Management are examined in light of the anticipated future rise of modern applications of Machine Learning Methods. The supply chain encompasses all the steps taken from the point of creation to the point of sale. The supply chain consists of several moving parts, including personnel, raw materials, information, gearbox mechanisms, and vehicles. Each of these entities is essential to the next in the procurement-to-fulfillment process. As an example of reverse logistics in action, consider the waste management and recycling practises of the fast fashion industry. The supply chain is just one aspect of what amounts to a circular process.

Closed-loop supply chain management:-

A closed-loop supply chain (CLSC) is simply the union of two supply chains: the conventional supply chain (also known as the "forward supply chain") and the "reverse supply chain," which involves the return of used products from consumers to producers. Simply said, a reverse supply chain is one in which used goods are collected from consumers and returned to the original manufacturer for refurbishment. According to Haynsworth and Lyons (1987), "remanufacturing is the process of restoring an item to near-new condition by replacing and rebuilding its component parts." The conventional supply chain begins at the factory and ends with the final customers. Remanufacturing completes the cycle, as shown in Figure 1.2. There are a number of stages in the recycling/recovery process (Matsumoto & Ijomah, 2013). The steps involved are as follows: (i) collecting the rejected products; (ii) disassembling them; (iii) cleaning and purifying components; (iv) checking and sorting; (v) remanufacturing and replacing parts; (vi) reassembling everything; and (vii) reviewing the results.

Demand pattern:-

Demand, which is synonymous with need or demand, drives all activities in a market. Demand may be fixed or classified into several forms, such as continuous demand, dependent demand, random demand, etc. based on the product's past performance. The need is unchanging regardless of the degree of complexity since it is always there. Price, quality, timing, stock, greenness, warranty, marketing effort, etc. may all affect dependent demand. The need may occur alone or in a number of different ways. It is not possible to extrapolate the demand for a product based on its past performance or lack thereof, as is the case with recently introduced items. The most realistic and useful method for doing business is based on a random demand. Demand in markets is volatile and difficult to foresee in today's global economy. The best demand pattern may be determined in this case by continuous research on product demand over several time cycles.

Reverse logistics:-

The Term "Reverse Logistics" Refers To The Practise Of Transporting And Storing Goods So That They May Be Returned From The Buyer To The Seller. Reasons For This Return Traffic Include Receiving A Damaged Goods, A Product With A Functional Value That Is Lower Than Expected, A Better Price Or Discount On The Same Product From A Different Brand, Etc. There Are Several Advantages: There Are Several Advantages To Recycling Rejected Goods, Including (I) Financial Gain For The Manufacturer(S), (Ii) Enhanced Communication Among Supply Chain Partners, (Iii) Promotion Of The Manufacturer's Green Credentials Via The Reuse Of Waste Products, (Iv) Continued Satisfaction On The Part Of The Company's Clientele, And (V) Protection Of The Environment. Managers (Logisticians) In Charge Of The Reverse Logistics Process Make Decisions Like Whether A Product Should Be Sent Back To The Factory, To The Store For Resale At A Discount, To Inspection Centres For Quality Control, And So On.

2. Literature Review:-

A common definition of a supply chain is the group of companies that collaborate to provide products and services to customers (Lambert, D. M. et al., 1998). Despite the extensive research into the supply chain, academics have yet to settle on a unified theory or set of principles (Jones & Riley (1985), Ayers,J. B.(2001), Mentzer, et al. J.(2001), Chopra et al. (2007), Feniès(2006)). Each offers a definition that is informed by the discipline it was developed in and the research issues that inspired it. Definitions might focus on the product itself, or they can focus on the business or a specific process. One of the first definitions of SC was proposed by Jones and Riley (1985): "planning and piloting the whole material flow from the source to the ultimate consumer through the manufacturer and distributor." According to (Chopra & Meindl, 2001), the phrase encompasses everything that plays a role in the fulfilment of a customer's purchase. Logistics companies, warehouses, distributors, retailers, and customers complete the chain that begins with manufacturers and wholesalers.

The Supply Chain, in its most basic definition, includes all the steps involved in taking an order and turning it into a finished product or service that has been paid for by the customer. Therefore, everything from initial raw material procurement through final customer delivery is included in the Supply Chain. The supply chain is the network of businesses ("links") that collaborate from the point of an idea's inception to the point of its eventual disposal (after-sales service and withdrawal logistics) in order to keep a product or service in circulation. Customers today expect a level of service that is tailored to their unique needs, be they related to how quickly a product is delivered, how often stock is replenished, how long the service is unavailable, how securely sensitive information is transmitted, or how discreetly money is handled. As a consequence, organisations of all stripes are incorporating data collection and direct transfer tactics into their packaging, restocking, and forecasting practises in preparation for the ultimate customer sale. The increasing complexity of contemporary Supply Chains may be attributed to a number of factors, including globalisation, an expansion in the types of flows, and the emergence of global consumer trends.. Supply chain management's overriding objectives are the preparation for orders and deliveries and the assurance of the supply and storage of products and raw materials. It consists of many subcomponents, including:

- Planning for anticipated demand,
- Planning for anticipated production,
- Managing inventory, and
- Managing transportation.

Based on these principles, it seeks to minimise costs connected with product inventory, shipping, and distribution. There are several potential advantages to achieving supply chain excellence, such as "zero stock," just-in-time delivery, and, most crucially, the end of stock shortages throughout the world.

In this way, the supply chain may be viewed of as an interconnected network of companies that coordinate their efforts to maximise efficiency and effectiveness in the delivery of all services at any given moment. Utilising IT and facilitating the free flow of data across the multiple networks of companies along the product's path to the customer helps enhance all of these factors.

In order to thrive in the next years, businesses will need to significantly enhance their supply chain management. The constant push from clients for more convenient services at lower prices, the introduction of new competitors, and the ever-increasing complexity of available technology are just a few of the many reasons why businesses are always adapting. When it comes to AI and ML, "supervised learning" refers to a setup where both input data and predicted output data are supplied. Labelling the input and output data for categorization provides a foundation for future learning and processing. Knowledgeable quantities that will back up future judgements are fed into the learning algorithms by supervised machine learning systems (Kuo, R. J., & Li, P. S., 2016). Pairs of input subjects and predicted outputs (also called supervisory signals) are utilised as training data in supervised learning (Makkar, S.,Devi,G. N. R., & Solanki, V. K., 2019). Decisions made by these models are more likely to be understandable by people because of the emphasis placed on human input. However, supervised learning systems struggle to comprehend novel data when they rely on a retrieval-based strategy. Learn Without Being Watched In contrast to the annotated examples used in supervised learning, the algorithm in an unsupervised setting must rely on unlabeled data. Since it lacks the ability to learn from experience, like animals and people do, it must produce the categories to correlate with the data supplied to it automatically (Makkar, S.,Devi,G. N. R., & Solanki, V. K., 2019). Segmentation (or clustering), the process of separating data into groups (category, class, cluster...) such as categorising photographs of vehicles, kittens, etc., is the most prevalent unsupervised learning task. Predictive maintenance, cybersecurity, early illness diagnosis, etc. all place a premium on anomaly detection. To classify the data, for example, one may use an algorithm based on the data's density or density gradient, and this algorithm's goal is to increase the degree to which the data within each group is similar to one another. Instead of looking for the most common numbers or patterns, anomaly detection focuses on the outliers. The underlying measure is crucial in deciding what is typical and what is abnormal (Zhou,L., et al., 2017). - Memory Retention Machine Learning helps a computer to figure out how to solve a problem on its own, rather than being explicitly told how to do so. There are several algorithms relevant to this area of research. These algorithms may generate mathematical rules from data by training themselves on the basis of examples, and then apply these rules to fresh data by continually improving with experience, earning them the moniker "trainable systems." SVM (Support Vector Machine), boosting, random forests, neural networks, Bayesian networks, etc. are all examples of popular algorithms. They may be used in many different situations. They may function in a number of settings, such as being supervised, semi-supervised, or unsupervised; using reinforcement; operating in sequential or batch mode; etc. They take in data (picture, sound, text) and spit out results (category of item in image, word uttered, topic of text), forming what is known as a "input-output" system. This enables computers or machines to be equipped with vision, identification of things (faces, diagrams, natural languages, writing, grammatical structures), and other types of perception of their surroundings, allowing them to carry out all activities requiring the entry and classification of data.

3. Overview of Machine learning:-

Machine learning is a branch of AI that enables a computer programme or system to pick up new skills and adapt to its environment with little to no human guidance. Data or observations are utilized in ML to create a computational model, which is then used to enhance predictions or performance. The technologies functioning. Algorithmic models of machine learning (ML) are very effective in sifting through large datasets in search of patterns, outliers, and predictive insights. Because of its robust capabilities, it is an excellent choice for resolving important issues in the supply chain sector. There are primarily three types of algorithms that may be distinguished by the training data they use and the final output they provide. These groups are distinguished by their unique approaches to learning.

4. Problem Description:-

The primary goal of this work is to remanufacture previously used things in an effort to reduce waste and keep the economy stable. Many businesses are willing to take on the recovery process because of the extra value it provides. It's possible that many electronic items that have reached the end of their useful life cycle are collecting components with economic worth. Mixing metals salvaged from recycled goods with new raw materials has the potential to lower steel manufacturing costs. Closed-loop supply chains, on the other hand, are made up of the collecting of discarded items from the market and their subsequent incorporation into the downstream flow of resources. Products that are still in excellent shape but are no longer being utilised because their owners want something with more features or more up-to-date technology are occasionally returned. Therefore, a process of inspection, selection, or sorting is required to establish the quality of recycled materials from the old products that are submitted. Used goods may be returned in a variety of ways from consumers. The manufacturer may choose to collect the used goods via his own channels, to engage a third party to do so, or to have the merchant collect on his behalf. Most production runs are now automated to save time, energy, and ensureerror-free output in today's fast-paced commercial world. However, there are other items that demand human creativity rather than a machine's. Think about the production of high- end leather items or clothes, for which human intervention is essential. Incorporating humans into the production process brings with it their fallible (learning-forgetting) makeup. In circumstances of repeated tasks, the learner's nature shines through. Workers gain confidence and efficiency as the number of repetitions grows. Wright (1936b) provided a useful definition of 'learning' as a human attribute by use of a curve called a 'learning curve. Based on the theory, we may infer that there will be a fixed percentage decrease in costs when production doubles. The literature generally focuses on the forward channel of production when discussing learning. How does employee education affect the manufacturing and remanufacturing of final goods in a closed-loop supply chain? What should be done if, in a closed-loop scenario, the lead time for product delivery from the producer to the store is uncertain? The delivery lead time is not a constant in practise for a number of reasons, including but not limited to transportation delays, manufacturing delays, and loading and unloading delays. In this study, we explore stochastic delivery lead time and examine its influence along with worker learning in production on the performance of the related closed-loop supply chain in order to address the aforementioned issues. We think of a production facility and a retail outlet as part of a closed-loop supply chain. A single product is manufactured by the producer and sent to the merchant in lots. The shop acts as the manufacturer's agent, collecting returns from consumers and shipping them back to the firm for refurbishment. Nonetheless, the original outlay and storage fees for returned goods are on the manufacturer. In addition to this, we presume the following: Investment in collection and product demand affect (i) the return rate of used products. In this case, the investment is intended to motivate end users with a little outlay of resources, with the expectation of a substantial payoff. (ii) Once used objects have been gathered, they are examined. Only a small percentage (0 1) of remanufacturable old goods are actually approved after being examined. (iii) There is no variation in either the rate of demand or the rate of production of the final product. There is an excess of supply over demand. (iv) The time it takes to get a shipment to a store is random and unrelated to when other shipments arrive. (v) The retailer's stock is monitored in real time, and a batch order is placed when inventory decreases below a threshold. (vi) The store is permitted to operate with a severe backlog of inventory. (vii) Production and refurbishment are combined into a single facility. Products that have been remanufactured are identical in quality to those

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that have been built from scratch (Clark and Scarf, 1960). (viii) In order to create one completed product, one raw material must be used. (ix) Development happens throughout manufacturing and refurbishment of the final product. The pace at which learning increases the rate of output relies on the duration of the production interval.

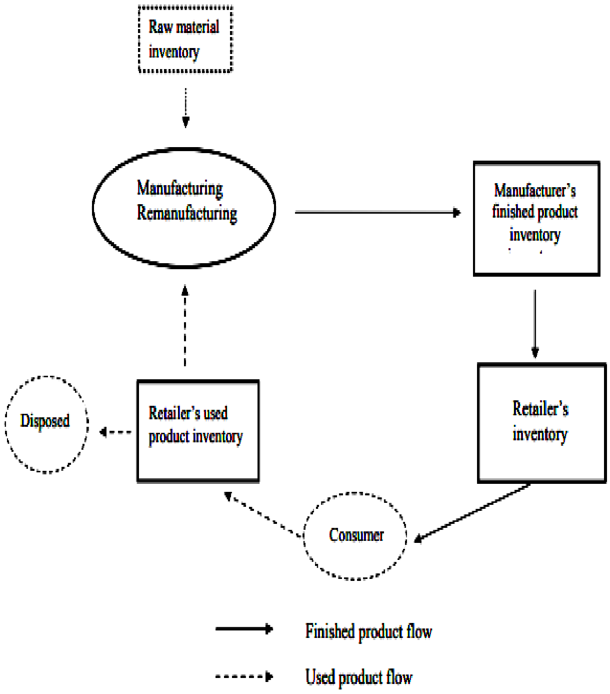

Figure 1: Product flow diagram.

5. Methodology:-

There are three significant steps need to adopt machine learning in supply chain management.
They are:
a) Understand your supply chain's structure Before implementing machine learning into your supply chain, you should evaluate your entire supply chain's structure:
• The first step is determining the critical components in company's operations.
• Next step is conducting a detailed analysis of the supplier network including Tier 1 suppliers and sub-tier suppliers.
• Thirst step is to Identify hidden relationships and nodes of interconnectivity.
• Then, Quantitatively diagnose the relative fragility of the supply chain.
• Next Step is to identify bottlenecks and risk factors in the supply chain
• Sixth step is to draw meaningful comparisons with peers and industry benchmarks
• Seventh is to assess the security of the supply chain.
• Finally, evaluate your functional maturity against the process, people, and technology.
b) Setting up open KPIs for the company and figuring out the return on investment To identify whether machine learning use cases in your supply chain will provide a positive return on investment, businesses must first undertake a Discovery Phase. Estimate total cost of ownership and profitability over the long and short term after ROI has been computed. Creating a comprehensive strategy for outlining the company's objectives and the resources it will take to achieve those objectives is equally crucial. Aligning machine learning KPIs with business KPIs is essential for removing discrepancies. That is to say, the business challenge should be stated in terms of Machine Learning.
c) Ensuring an effective ML engineering process Machine learning use cases in the supply chain depending on the following aspects:
• Set up a multifunctional team of professionals with expertise in data science, DevOps, Python, Java, QA, business analysis, etc.
• Start with a business problem statement and establish the right success metrics.
• Choose the right tech stack to consider your data readiness by focusing on data quality and quantity.
• Develop, train, test, and optimize models.
• Deploy and retrain models where needed.
• Monitor the performance of model used in Machine Learning.

6. Results:-

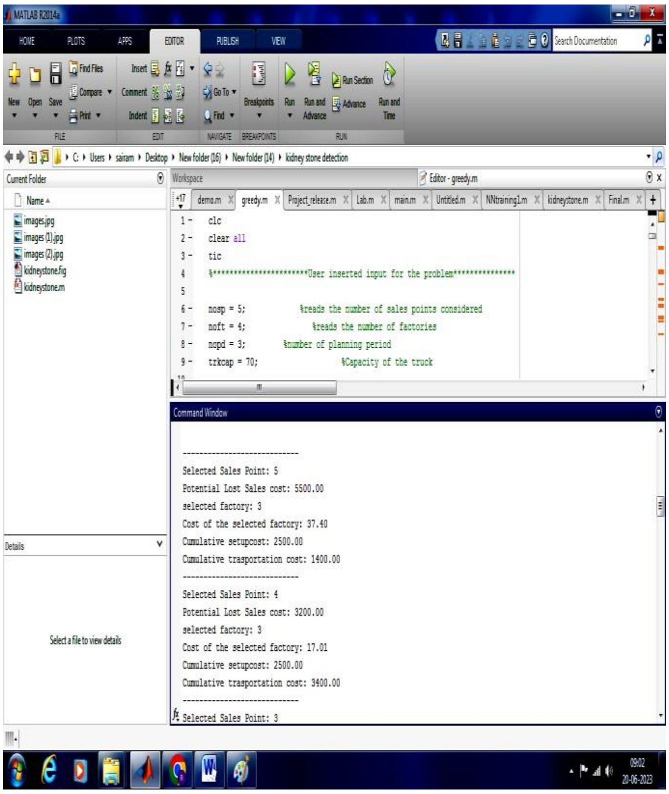

Figure 2.output Variance with Sales point

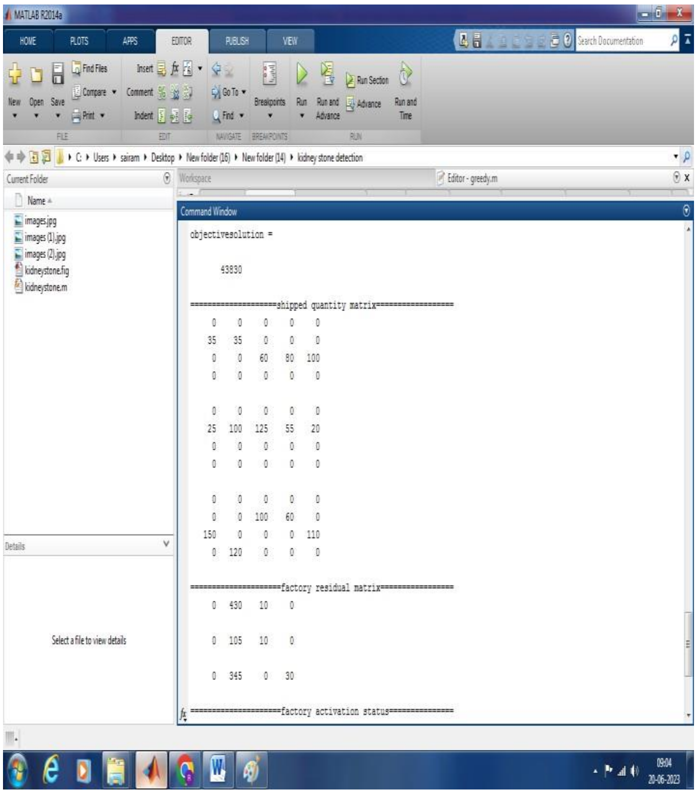

Figure 3.output Variance with Residual Matrix

Figure 2 Shows the changes in percentage error for different learning rates. It can be seen that as the learning rate goes up, the decrease in percentage error becomes faster. A greater learning rate implies a higher chance to decrease the inspection error, and the declined inspection error eventually indicates a reduced penalty cost which results in a better annual expected profit

Figure 3 shows that for learning exponents above 0.4, the error in inspection almost does not exist after approximately 16th cycle. Therefore, the errorless inspection process will obviously suppress the imperfect inspection. As a result, the profit in 'no learning in production' case intersects and leaves behind the other one

Now, we compare our assumption of S-shaped learning curve with Wright's learning curve in inspection taking the same initial percentage error. If we follow the trend of the average expected profit, we can observe a huge difference all over the cycles. Wright's learning works from the very beginning and gradually reaches a plateau (Figure 4). This causes a profit growth for the initial cycles and then it becomes almost constant. But in S-shaped learning curve, the initial stage is about being familiar with the tasks where learning occurs

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slowly. After that, the learning rate drives the inspection process, and makes it so high that it turns into nearly errorless. This results in a major profit growth which leaves behind the other profit curve after a certain number of cycles. So for a long run, our model with S-shaped learning is better than using Wrights learning in inspection process.

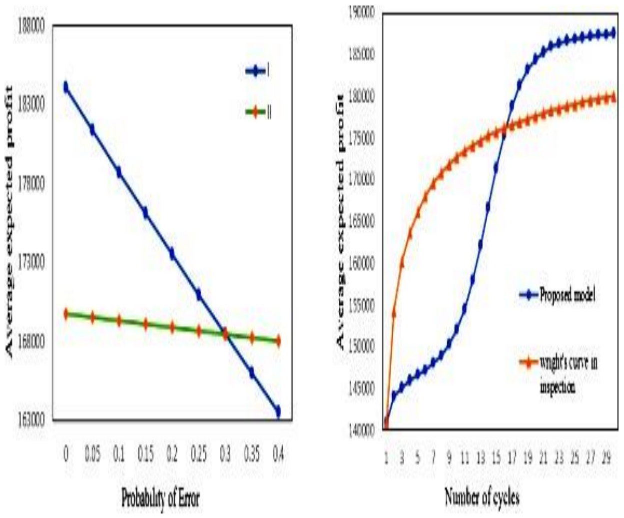

Fig. 4: Behavioral pattern of Type I and Type II

7. Conclusion:-

The focus of this study was to investigate the current state of machine learning (ML) applications across the supply chain. Here, after a brief introduction to the most popular ML techniques, we demonstrated how the supervised, unsupervised, and semisupervised approaches might be put to use in different areas of the supply chain. Thus, the most important facets of SCM were discussed, such as how to choose suppliers, how to divide suppliers into groups, how to forecast risks in the supply chain, how to estimate customer demand, how to manage inventory and transportation, and how to create a sustainable and efficient economy. In the discussion of selecting a supplier, two machine learning methodologies were outlined. We first spoke about how to integrate DT and P-SVM into the vendor selection process. Second, a new RL method called Q-learning was developed to help with the problematic supplier selection process. In the following paragraphs, I will describe how to divide suppliers into distinct groups using a hybrid MCDM/FCM strategy and ecological considerations.Companies may improve their supply chain's profitability, efficiency, and access to resources by making long-term investments in machine learning and associated technologies today.

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